

**COMPARISON OF CHANGE IN OBESITY PARAMETERS AND THE
RELATIONSHIP BETWEEN CHANGES IN BODY COMPOSITION AND
PHYSIOLOGICAL AND PSYCHOLOGICAL HEALTH STATUS**

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ABSTRACT

Given the seriousness of obesity as a health issue, accurate measures of obesity are important for research, diagnostic and weight loss programmes. The standard accepted measure is body mass index (BMI), but over-reliance on BMI and body mass is a limitation of current research and the need for more sensitive measures of body composition is recognised. The work described in this thesis compared the utility of traditionally used anthropometric measures (TAM)¹ with alternative anthropometric measures (AAM)².

Study One compared change in TAM with change in AAM in individuals on a self-determined weight loss programme. It was hypothesised that AAM would show greater magnitudes of change than TAM. Level I ISAK³ anthropometric assessments were conducted monthly on 10 male (58.5 ± 16.5 years) and 50 female (52.2 ± 14.9 years) overweight/obese individuals over a year. $\Sigma 8SF$ and endomorphy showed significantly greater magnitudes of change than body mass and WHR, however comparable magnitudes of change to BMI and %BF. Thus, the hypothesis was accepted for $\Sigma 8SF$ and endomorphy compared to mass and WHR only. $\Sigma 8SF$ represents body composition and does not require transformation from other variables. Furthermore, it showed significant change that weight-related parameters failed to identify. Therefore it is concluded that this measure could be used to monitor weight loss. Conversely, the benefits of somatotype were less evident and due to the time and expertise required to obtain these measures, it is concluded that somatotype should not be considered for routine use.

Study Two examined if anthropometric measures were correlated with psychological risk factors. Participants in Study One completed Fox & Corbin's Physical Self-Perception Profile (PSPP) measuring constructs of

¹ Traditionally used anthropometric measures (TAM): BMI, body mass, waist-hip-ratio (WHR) and percent body fat (%BF).

² Alternative anthropometric measures (AAM): sum of 8 skinfolds ($\Sigma 8SF$), global somatotype and somatotype sub-components; endomorphy, mesomorphy and ectomorphy.

³ International Society for the Advancement of Kinanthropometry (ISAK)

physical condition, body attractiveness and physical self-worth. It was hypothesised that AAM would show stronger correlations to PSPP constructs than TAM. Findings identified that high BMI, body mass, %BF, $\Sigma 8SF$ and endomorphy were associated with low physical self-perceptions. However there were no differences in the strength of relationships with AAM or TAM, and changes in PSPP constructs showed weak correlations with changes in both measures. Thus the hypotheses were rejected. It is concluded that focusing on health-related behaviours, as opposed to reducing anthropometric measures, may be a more constructive approach to reducing obesity.

Study Three tested the hypothesis that AAM would show stronger associations to markers of metabolic syndrome (MetSyn) than TAM. Level I ISAK³ profiles were conducted on 6 male (47.9 ± 18.0 years) and 20 female (43.4 ± 17.4 years) overweight/obese participants on self-determined weight loss programmes. Blood markers⁴ were measured through capillary fingertip blood samples. Waist circumference, systolic and diastolic blood pressure were recorded to obtain all the diagnostic criteria for MetSyn. All measures were repeated after a 6-month interval. BMI and mass showed strongest correlations with MetSyn markers and moderate relationships were identified between weight loss and improvement in MetSyn components. The hypothesis was rejected. It is concluded that the clinical utility of somatotype measures in assessing change in MetSyn status appears limited and weight loss should be the first line treatment of MetSyn.

In conclusion, somatotyping appears to have limited utility for monitoring change in overweight/obese individuals and no obvious benefit in assessing an individual's health status from a physiological or psychological standpoint. However $\Sigma 8SF$, that reflects changes in body composition and is sensitive to change, may be a useful measure to monitor weight loss in overweight/obese individuals.

³ ISAK: International System of the Advancement of Kinanthropometry

⁴ Blood markers: High density lipo-protein cholesterol, blood glucose and triglycerides

CONTENTS

ABSTRACT	
TABLE OF CONTENTS	
DECLARATION	i
LIST OF TABLES	ii
LIST OF FIGURES	v
LIST OF BOXES	viii
LIST OF ABBREVIATIONS	ix
ACKNOWLEDGEMENTS	xi
CONFERENCE PROCEEDINGS	Xii
CHAPTER 1: INTRODUCTION.....	1
1.1 Statement of the problem.....	1
1.2 Purpose and significance of research.....	3
1.3 Summary of individual chapters.....	5
CHAPTER 2: REVIEW OF LITERATURE.....	8
2.1 Obesity.....	8
2.1.1 Defining obesity.....	8
2.1.2 Prevalence of obesity.....	10
2.1.3 Etiology of obesity.....	11
2.2 Measurement of obesity.....	14
2.2.1 Current indices of obesity.....	14
2.2.1.1 Weight related parameters.....	14
2.2.1.1 Waist Circumference/Waist-Hip-Ratio.....	16
2.2.2 Assessing body composition.....	19
2.2.2.1 Levels of human body composition.....	19
2.2.2.2 Measurement techniques.....	20
2.2.2.3 ISAK.....	25
2.2.2.4 Levels of Validation.....	26
2.2.3 Somatotyping.....	28
2.2.3.1 Somatotype rating.....	29
2.2.3.2 Endomorphy.....	30
2.2.3.3 Mesomorphy.....	31
2.2.3.4 Ectomorphy.....	31
2.3 Importance of measuring body composition.....	34
2.4 Obesity and its consequences.....	36
2.4.1 Financial consequences of obesity.....	36
2.4.2 Physiological consequences of obesity.....	38
2.4.2.1 Obesity and co-morbidities.....	38
2.4.2.2 Obesity and metabolic syndrome.....	39
2.4.3 Psychological consequences of obesity.....	45

CHAPTER 3: GENERAL METHODS AND INSTRUMENTATION.....	49
3.1 Anthropometrical data collection.....	49
3.1.1 Equipment.....	51
3.1.2 Data handling.....	51
3.1.3 Technical error measurement.....	53
3.2 Approaches to somatotype analysis.....	58
CHAPTER 4: STUDY ONE – Longitudinal change in anthropometric measures.....	64
4.1 Introduction.....	64
4.2 PART A	60
4.2.1 Aims and hypotheses.....	68
4.2.2 Methods.....	68
4.2.2.1 Study design and participants.....	68
4.2.3 Procedures.....	70
4.2.3.1 Statistical analyses.....	70
4.2.3.1.1 Tests of normal distribution.....	70
4.2.3.1.2 Tests of difference.....	71
4.2.4 Results.....	71
4.2.5 Discussion.....	78
4.2.6 Conclusion.....	84
4.3 PART B.....	85
4.3.1 Aims and hypotheses.....	85
4.3.2 Methods.....	85
4.3.2.1 Study design and participants.....	85
4.3.3 Procedure.....	85
4.3.4 Data analysis considerations for the measurement of change.....	86
4.3.4.1 Growth and change.....	86
4.3.4.2 Multiple waves of data.....	87
4.3.4.3 Time metric.....	89
4.3.4.4 Systematic change.....	89
4.3.5 Data analysis considerations for the measurement of change in Study One, Part B.....	90
4.3.6 Data handling and statistical analysis for Study One, Part B.....	96
4.3.7 Results.....	96
4.3.7.1 Change in anthropometric measures.....	98
4.3.7.2 Comparison of magnitude of change.....	103
4.3.8 Discussion.....	106
4.3.8.1 Change in anthropometric measures.....	106
4.3.8.2 Comparison of magnitude of change.....	110
4.3.8.3 Limitations.....	112
4.3.8.4 Future directions.....	113
4.3.9 Conclusion.....	114

CHAPTER 5: STUDY TWO – Anthropometric measures and physical self-perceptions.....	115
5.1 Introduction.....	115
5.2 Aims and hypotheses.....	123
5.3 Methods.....	124
5.3.1 Study design and participants.....	124
5.4 Procedures.....	125
5.4.1 Anthropometric data collection.....	125
5.4.2 Use of the PSPP.....	125
5.4.3 PSPP data collection.....	126
5.4.4 Statistical analyses.....	126
5.4.4.1 Tests of normality.....	127
5.4.4.2 Tests of difference.....	127
5.4.4.3 Correlation analysis.....	127
5.5 Results.....	128
5.5.1 Baseline relationships between anthropometric measures and PSPP component scores.....	129
5.5.2 Change in PSPP measures over time.....	130
5.5.3 Relationship between changes in anthropometric measures and changes in PSPP component scores.....	132
5.6 Discussion.....	135
5.6.1 Baseline relationships between anthropometric measures and PSPP component scores.....	135
5.6.2. Relationship between changes in anthropometric measures and changes in PSPP component scores.....	138
5.6.3. Relationship between changes in anthropometric measures and changes in PSPP component scores.....	139
5.6.5 Limitations.....	145
5.6.6 Future directions.....	146
5.7 Conclusion.....	146
CHAPTER 6: STUDY THREE – Anthropometric measures and metabolic syndrome.....	148
6.1 Introduction.....	148
6.2 Aims and hypotheses.....	150
6.3 Methods.....	150
6.3.1 Study design and participants.....	150
6.4 Procedures.....	151
6.4.1 Anthropometric data collection.....	151
6.4.2 Met Syn data collection.....	152
6.4.2.1 Use of CardioChek PA.....	152
6.4.3 Statistical analyses.....	157
6.4.3.1 Tests of normality.....	157
6.4.3.2 Tests of difference.....	157
6.4.3.3 Correlation analysis	158
6.5 Results.....	158
6.5.1 Prevalence and baseline characteristics.....	158

6.5.2 Baseline relationships between anthropometric measures and MetSyn components in all individuals.....	163
6.5.3 Change in anthropometric measures and MetSyn components.....	163
6.5.3.1 Individuals with MetSyn.....	167
6.5.3.2 All individuals (with and without MetSyn).....	
6.5.4 Relationship between changes in anthropometric measures and changes in Met Syn components in individuals with Met Syn.....	168
6.5.5 Relationship between changes in anthropometric measures and changes in Met Syn components in all individuals (with and without MetSyn).....	169
	170
	170
6.6 Discussion.....	
6.6.1 Prevalence and baseline characteristics.....	172
6.6.2 Baseline relationships between anthropometric measures and MetSyn components in all individuals.....	174
6.6.3 Relationship between changes in anthropometric measures and changes in Met Syn components.....	174
	176
6.6.3.1 Individuals with MetSyn.....	178
6.6.3.2 All individuals (with and without MetSyn).....	179
6.6.4 Limitations.....	180
6.6.5 Future directions.....	
6.7 Conclusion.....	
CHAPTER 7: SUMMARY.....	182
7.1 Revisiting original aims.....	182
7.1.1 Study One.....	182
7.1.2 Study Two.....	183
7.1.3 Study Three.....	183
7.2 Summary of findings and practical implications.....	184
7.3 Limitations.....	187
7.4 Recommendations for future research.....	188
7.5 Final comment.....	189
REFERENCES.....	190
APPENDICES.....	226
Appendix 1 – Anthropometry accreditation levels.....	226
Appendix 2 – Restricted and full anthropometric profiles.....	227
Appendix 3 – Anthropometry equipment.....	228
Appendix 4 – Intra- and Inter-technical error of measurement levels....	229
Appendix 5 – Participant information sheet (Study One and Three)....	230
Appendix 6 – Physical activity readiness questionnaire (PAR-Q).....	231
Appendix 7 – Consent form (Study One and Three).....	233
Appendix 8 – GP referral form.....	234
Appendix 9 – Participant information sheet (Study Two).....	235
Appendix 10 – Participant food and exercise diary.....	236
Appendix 11 – Physical self-perception profile.....	239
Appendix 12 – Physical self-perception profile scoring sheet.....	241
Appendix 13 – Participant information sheet (Study Three).....	242
Appendix 14 - Consent form (Study Three).....	244

DECLARATION

‘Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.’

Nicola Brown

LIST OF TABLES

CHAPTER 2

2.1. Weight classification based on BMI (kg.m^{-2}) (National Audit Office, 2001).....	9
2.2. Adults (<16years) reaching recommended guidelines for physical activity levels by body mass index and gender in England, 2003 (adapted from Health Survey for England, 2003:).....	13
2.3. Strengths and limitations of WHR and WC.....	18
2.4. Body composition terminology (Morgan & Madden, 1996).....	20
2.5. Capability of different body fat measurements to estimate total body fat and fat distribution (reproduced from Snijder, 2006).....	23
2.6: Levels of validation of body composition methods (Hawes & Martin, 2001)	26
2.7: Characteristics associated with different ratings for endomorphy, mesomorphy and ectomorphy (Norton & Olds, 1996).....	33
2.8: Features of the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP-III), International Diabetes Federation (IDF), World Health Organisation (WHO), and the European Group for the Study of Insulin Resistance (EGIR) definitions of MetSyn (Adapted from Byrne & Wild, 2006).....	41

CHAPTER 3

3.1. Measurements included in a restricted anthropometric profile.....	49
3.2. Mean (\pmSD) and intra-TEM of anthropometrical measures in 3 population groups; overweight (n=20), obese (n=20), and morbidly obese (n=16).....	55
3.3. Somatotype categories and corresponding dominance variation, as defined by Carter and Heath (1990).....	59

CHAPTER 4

4.1. Mean (\pmSD) time (days) between measurement sessions over four month testing period.....	70
4.2. Mean (\pmSD) baseline demographic measures and traditional and alternative anthropometric measures for all participants involved in Part A of Study One (n=90), including breakdown by gender and BMI classification.....	74
4.3. Mean change of all anthropometric variables between months and between baseline and month four (n=90).....	67
4.4. Mean (\pmSD) time (days) between measurement sessions over the 12 month testing period.....	86
4.5. Studies utilising percent weight change and percent BMI as main outcome variables.....	91
4.6. Risk categories for select anthropometric variables and their capacity for change (for females).....	92
4.7: Phantom means and standard deviations (Ross & Marfell Jones, 1991).....	94
4.8: Mean (\pmSD) baseline demographic and anthropometric measures for all participants involved in Part B of Study One (n=60), including breakdown by gender and BMI classification.....	97
4:9: Number of subjects at each time point, grouped by gender and BMI classification, and retention rates over the 12 month period (%).....	98
4.10: Mean change between months in traditional and alternative all anthropometric variables (n=60).....	102

CHAPTER 5

5.1: Relationship (Pearson's correlation coefficient) of anthropometric indices with PSPP construct scores at baseline (n=60).....	130
5.2: Relationship (Pearson's correlation coefficient) of change in anthropometric indices with change in PSPP construct scores from baseline to month 12 (n=60).....	133
5.3: Relationship (Pearson's correlation coefficient) of change in anthropometric indices with change in PSPP construct scores between three separate time periods; baseline-month 4, months 4-8, months 8-12 (n=60).....	134

CHAPTER 6

6.1: CRMLN cholesterol certification criteria, based on meeting recommendations from the National Cholesterol Education Programme (NCEP) (Myers et al., 2000).....	153
6.2: NCEP goals for lipids stated as total error (Warnick et al., 2002)....	154
6.3: CardioChek PA System CRMLN and NCEP results for TC, HDL-C and LDL-C (Polymer Technology Systems Inc, 2007).....	155
6.4: Lipid panel precision testing Polymer Technology Systems Inc, 2003).....	156
6.5: Mean (\pm SD) baseline demographic and body composition measures for all participants who completed Study Three (n=26), including breakdown by gender and BMI classification.....	160
6.6: Metabolic and haematological baseline characteristics of individuals with and without metabolic syndrome (n=26).....	161
6.7: Relationship (Pearson's correlation coefficient) of anthropometric indices with components of the metabolic syndrome at baseline in all individuals (n=26).....	162
6.8: Relationship of change in anthropometric variables (pre and post) with change in components of the MetSyn in individuals with MetSyn (n=14).....	168
6.9: Relationship of change in anthropometric variables (pre and post) with change in components of the metabolic syndrome in all individuals (n=26).....	169

LIST OF FIGURES

CHAPTER 2

2.1. Secular trend in the prevalence of obesity (% with BMI>30kg.m ⁻²) in Health Survey for England in men and women (Rennie & Jebb, 2005).....	10
2.2. The five levels of human body composition according to Wang et al. (1992).....	19
2.3. Bodies displaying endomorphic (a), mesomorphic (b) and ectomorphic (c) characteristics (bodytypes.wordpress.com, 2008)	32
2.4. Effect of exercise on composition of weight loss (Pavlou et al., 1985).....	34
2.5. Assumed vs. actual changes in body fat after resistance or aerobic exercise (Prentice & Jebb, 2001).....	35
2.6. Progression and outcome of the MetSyn (Grundy, 2006).....	42

CHAPTER 3

3.1: Landmarks for iliac crest (A) and supraspinale skinfolds sites (B) and examples of abdominal skinfold (C) and iliac crest skinfold (D) measurements (Ross et al., 1999).....	50
3.2: Examples of skinfold measuring technique (healthgoods.com, 2008).....	50
3.3: Examples of arm relaxed and gluteal girths (E&F, respectively) and humerus breadth (G) and femur breadth (H) measurements (Ross et al., 1999).....	50
3.4: Intra-observer TEM (%) of anthropometrical measures in 3 population groups; overweight (n=20), obese (n=20), and morbidly obese (n=16).....	57
3.5: 2-D somatochart showing co-ordinates and somatotype categories (Norton & Olds, 1996), with 3 example somatocharts plotted to illustrate SAD and MD.....	60

CHAPTER 4

4.1. Breakdown of current dietary methods/services utilised by participants (n=90) at baseline.....	72
4.2 Breakdown of current physical activity methods/services utilised by participants (n=90) at baseline.....	72
4.3. Somatotype distribution of participants (n=90) at baseline (a) and month 4 (b).....	73
4.4. Mean somatotype (n=90) at baseline and month 4.....	75
4.5. Mean change of alternative anthropometric measures from baseline to month 4 (n=90).....	76
4.6. Mean change of traditional anthropometric measures from baseline to month 4 (n=90).....	76
4.7. Weight change (kg) in self-help group vs. commercial weight management programme over a 2 year period (Heshka et al., 2003).....	79
4.8. Weight loss patterns in 4 diet groups over 1 year (Gardner et al., 2007).....	80
4.9. Post-treatment weight change in 3 activity groups over 1 year (Andersen et al., 2001).....	81
4.10. Hypothetical weight loss (kg) over 6 months measured pre and post 6 months.....	88
4.11. Hypothetical weight loss over 6 months measured at monthly intervals over 6 months.....	88
4.12. Somatotype distribution of participants (n=60) at baseline (a) and month 12 (b).....	98
4.13. Somatotype distribution of participants (n=60) from baseline to month 12.....	99
4.14. Mean somatotype (n=60) at baseline and months 4, 8, and 12.....	100
4.15. Mean change in alternative anthropometric measures from baseline to month 12 (n=60).....	101
4.16. Mean change in traditional anthropometric measures from baseline to month 12 (n=60).....	101

4.17. Comparison of magnitude of change between traditional and alternative anthropometric measures from baseline to month 12 (n=60)	104
---	------------

CHAPTER 5

5.1: Hierarchical organisation of physical self-perceptions (Fox, 2001) and breakdown of sub-domain levels (Marsh, 1997).....	117
5.2: Mean PC, BA and PSW scores over time (n=60).....	131

CHAPTER 6

6.1: Number of simultaneous abnormalities observed amongst all participants at baseline and at final measurement (n=26).....	159
6.2: Number of individual metabolic abnormalities observed amongst all participants (n=26).....	159
6.3: Metabolic and haematological mean scores of participants with MetSyn (n=14) at baseline, mid and final measurement sessions.....	164
6.4: Mean scores for traditional anthropometric indices of individuals with Met Syn (n=14) at baseline, mid and final measurement sessions.....	165
6.5: Mean scores for alternative anthropometric measures of individuals with MetSyn (n=14) at baseline, mid and final measurement sessions.....	166
6.6: Mean somatotype (n=26) from baseline to month 6.....	167

LIST OF BOXES

CHAPTER 3

3.1: Equations to derive somatotype subcomponent scores (Carter, 2002)..... **52**

3.2: Equations to derive body density (Durnin & Womersley, 1974) and %BF (Siri, 1961)..... **53**

3.3: Equations to derive somatotype attitudinal distance (SAD), somatotype attitudinal mean (SAM) and migratory distance (MD) (Carter & Heath, 2005)..... **62**

LIST OF ABBREVIATIONS USED IN THIS THESIS

ACSM	American college of sports medicine
ADP	Air displacement plethysmography
BA	Body attractiveness
BIA	Bioelectrical impedance
BMI	Body mass index
BP	Blood pressure
CDC	Centre for Disease Control
Cm	Centimetre
CRMLN	Cholesterol reference method laboratory network
CT	Computerised tomography
CV	Cardiovascular
DBP	Diastolic blood pressure
DXA	Dual-energy x-ray absorptiometry
ECF	Extracellular fluid
ECS	Extracellular solid
HC	Hip circumference
HR	Heart rate
HSE	Health Survey for England
HWR	Height-weight-ratio
ISAK	International society for the advancement of Kinanthropometry
kg	Kilogram
MetSyn	Metabolic syndrome
MD	Migratory distance
mm	Millimetre
mmHg	Millimetres of mercury
mmol.L⁻¹	Millimoles per litre
MRI	Magnetic resonance imaging
NCEP-ATP III	National cholesterol education programme adult treatment panel III
NHANES	National health and nutrition examination survey

NHLS	National health laboratory service
p	Phantom value
PAR-Q	Physical activity readiness-questionnaire
PASW	Predictive analytical software
PC	Physical condition
PS	Physical strength
PSC	Physical Self-concept scale
PSDQ	Physical self-description questionnaire
PSPP	Physical self-perception profile
PSW	Physical self-worth
R	Coefficient of reliability
s	Phantom standard deviation
SAG-D	Sagittal abdominal diameter
SAD	Somatotype attitudinal distance
SAM	Somatotype attitudinal mean
SAV	Somatotype attitudinal variance
SBP	Systolic blood pressure
SC	Sport competence
SD	Standard deviation
SDD	Somatotype dispersion distance
SDM	Somatotype dispersion mean
SF	Skinfold
T2DM	Type II diabetes mellitus
TEM	Technical error of measurement
WC	Waist circumference
WHO	World Health Organisation
WHR	Waist-hip-ratio
%BF	Percent body fat
%TEM	Relative technical error of measurement
∑8SF	Sum of 8 skinfolds
2-C	Two-compartment
3-C	Three-compartment
4-C	Four-compartment

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CONFERENCE PROCEEDINGS

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Brown, N. (2010). Relationship between change in anthropometric variables and change in metabolic syndrome components. *2nd Canadian Obesity Student Meeting 9-12th June - University of Ottawa, Ontario.*

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1. INTRODUCTION

1.1 Statement of the problem

In 2005, the World Health Organisation (WHO) estimated that there were 1.6 billion overweight adults aged 15 years and above and at least 400 million obese adults, worldwide. Over the last quarter of a century the prevalence of obesity in Great Britain has almost trebled (Rennie & Jebb, 2005) and figures from the Health Survey for England (2007) estimated that 24% of men and 25% of women were classified as obese. In 2003, estimates identified that the UK had the highest percentage of deaths (8.7%) attributable to excess weight in Europe (Banegas et al., 2003).

The negative impact of obesity on health is considerable, including increased risk of several chronic diseases such as type II diabetes mellitus (Bray, 2003), hypertension (Francischetti & Genelhu, 2007), stroke (Abraham & Llewellyn-Jones, 2001), cardiovascular disease (Allender & Rayner, 2007; Hu et al., 2005) and cancer (McMillan et al., 2006). Moreover, obesity is associated with an increased risk of discrimination and bias in situations concerning employment (Pingitore et al., 1994; Roehling, 1999), healthcare (Oberrieder et al., 1995; Wadden et al., 2000) and education (Neumark-Sztainer et al., 1999). For some obese individuals these stigmatisations, discriminatory attitudes and behaviours can trigger or exacerbate psychological issues such as decreased mood, increased anxiety, low self-esteem and body image disturbances (Lawrence & Kopleman, 2004; Swinburn & Egger, 2004).

In addition to the negative physiological and psychological health outcomes associated with obesity, there is also an increasing economic burden of obesity on a national and global scale. Direct costs of obesity are estimated to cost the British economy more than £3.6 billion a year. Including all people who are overweight this cost could rise to between £6.6 and £7.4 billion

(Donnellan, 2003), and with the addition of the wider cost to the economy in lower productivity and reduced output, this could rise by a further £2.1 billion a year (National Institute for Clinical Excellence, 2003). Therefore, it is apparent that both the individual and economic costs of obesity are prevalent and development of appropriate strategies to counteract obesity is urgently needed.

Current projections suggest that the prevalence of overweight and obesity is likely to continue to rise (James, 2004) and it is evident that reliable and valid measures of adiposity are needed to monitor these changes (Nevill et al., 2006). The measurement of obesity is an area that has been extensively researched and the standard measure that is currently accepted is that of body mass index (BMI), measured in kg.m^{-2} (Carmichael, 1999; Romero-Corral et al., 2008). However, despite the ease and simplicity of this method, BMI does not distinguish fat from muscle, bone and other lean body mass (Burkhauser & Cawley, 2008; Garcia et al., 2005; Norton & Olds, 1996). Therefore, it is impossible to determine accurately if a fluctuation in body weight is due to a change in muscle, body water, or fat (Sargent et al., 2000) and BMI can give very misleading measures of the progress of fat loss (Prentice & Jebb, 2001). Furthermore, although weight gain associated with adverse physiological outcomes and increased morbidity, increases in a linear fashion with increases in BMI (Allan, 2004; Aronne & Segal, 2002), increased risk also relates to total body fat and body fat distribution (Burkhauser & Cawley, 2008; Eckel, 1997; Heyward & Wagner, 2004; Snijder et al., 2006).

Abdominal fat has been shown to provide an independent risk estimate beyond BMI alone (Sharma & Kushner, 2009), thus waist circumference (WC) and waist-to-hip-ratio (WHR) are anthropometric measurements recommended for routine use (Foreyt & St Jeor, 1997; Koning et al., 2007). Many researchers have declared WC the preferential method over the WHR to define obesity (Chan et al., 2003), thus WC is the preferred index for monitoring weight loss (Gibson, 2005). However, although in population

studies BMI and WC are considered reasonable surrogate measures of body and visceral fat, respectively (Lean et al., 1996; Rankinen et al., 1999), when applied to individuals they lack sensitivity and specificity (Eston, 2002; Wellens et al., 1996). Furthermore, changes in BMI and WC do not always reflect improvement in overall health or functioning (Sharma & Kushner, 2009).

Direct and indirect techniques to measure body constituents have been developed, with different levels of accuracy, practicality, and cost (Foreyt & Jeor, 1997; Sardinha & Teixeira, 2005). These include hydrostatic weighing, scanning by dual-energy x-ray absorptiometry (DXA), computerised tomography (CT), magnetic resonance imaging (MRI) and bioelectrical impedance (BIA) (Heyward, 2001; Pontiroli et al., 2002). Although these approaches achieve reliable results, the instrumentation is expensive, impractical for individual use and cannot be easily transported to test sites in large-scale intervention and epidemiology projects (Foreyt & Jeor, 1997; Van Loan, 1997).

1.2 Purpose and significance of research

Weight loss and weight management programme effectiveness are often based solely on participant weight change and/or change in BMI (Busetto et al. 2004; Dansinger et al., 2005; Ensrud et al., 2003; Roux et al., 2004; Thai & Wadden, 2005). However, there is much research evidence documenting the limitations of weight-related parameters to provide reliable assessment of body fat and its distribution over time (Burkhauser & Cawley, 2008; Garcia et al., 2005; Miller et al., 2000; Nevill et al., 2006; Sargent et al., 2001; Sharma & Kushner, 2009). Consequently, there is a need for measures of body composition that are sensitive to intra-individual change (Teixeira et al., 2005).

Determining the thickness of the skin at specific sites is the simplest and by far the most widely used method of gaining useful estimations of body fat

(Sharp, 1995). Together with girth measurements, they are useful for monitoring body composition changes over a period of time (Bean, 1996). As identified by Nevill et al. (2006), both BMI and skinfolds are encompassed in a further measurement system known as 'somatotype'. The method of somatotyping combines an appraisal of relative adiposity, musculo-skeletal robustness and linearity into a three number rating – summarising the physique as a unified whole (Gakhar & Malik, 2002; Kaur, 2009). Used to describe the changes in physique during growth, ageing and training, (Duquet & Carter, 2001), somatotype provides an accurate, detailed summary of individuals body composition (Norton, & Olds, 1996).

Somatotype is calculated from ten anthropometric dimensions including stretch stature, body mass, four skinfolds, two limb girths and two bone breadths. There are known limitations to the measurement of skinfolds, some of which tend to be accentuated in obese subjects (Van Loan, 1997). However, adequate training and practice, alongside the development of an accreditation scheme developed by the International Society for the Advancement of Kinanthropometry (ISAK), has contributed to the precision and reliability of results obtained through this method. Furthermore, when used appropriately, the tools of anthropometry, which are portable and relatively inexpensive (Bellisari & Roche, 2005), provide valid results (Stewart et al., 2003) and can be laboratory based or field based (Norton & Olds, 1996).

The measurement of skinfolds in overweight/obese individuals routinely takes place, despite the techniques' documented limitations (Cordero-MacIntyre et al., 2000; Mayo et al., 2003; Raatz et al., 2005; Slentz et al., 2004); however the application of somatotyping in an overweight/obese population has received little attention. Commonly used to describe the changes in physique during growth, ageing and training (Duquet & Carter, 2001), this technique may also identify changes in composition of obese individuals. As such, the main focus of the research is to examine and compare magnitudes of change in a range of traditionally used

anthropometric measures (BMI, body mass, WHR and percent body fat (%BF)), with alternative anthropometric measures (sum of 8 skinfolds ($\Sigma 8SF$), global somatotype and somatotype sub-components; endomorphy, mesomorphy and ectomorphy) over a 12 month period in an overweight/obese population. Throughout this thesis the phrases 'traditional anthropometric measures' and 'alternative anthropometric measures' will refer to the measures specified above.

The use of somatotyping, a more holistic measure of one's body, may also have utility in evaluating an individual's metabolic risk (Katzmarzyk et al., 2003) and may be a more useful method of assessing physique from a psychological perspective (Norton & Olds, 2002). Thus, secondary aims include investigating the relationship between somatotype and physiological variables (specifically metabolic syndrome markers) and psychological variables (specifically physical self-perceptions), in an overweight/obese population.

1.3 Summary of individual chapters

This chapter has provided a brief context to the research and has identified the purpose and significance of the research. Following discussion of the prevalence and aetiology of obesity, Chapter 2 moves on to review the techniques used to identify obesity and measure the composition of the human body, highlighting their strengths and limitations. The concept of somatotyping is introduced and the importance of monitoring body composition using measures that are sensitive to change is highlighted. Finally, the financial and health consequences of obesity are reviewed, focusing primarily on physiological and psychological health consequences.

Chapter 3 details the anthropometrical procedures utilised in all studies that comprise this thesis, following International Standards for the Advancement of Kinanthropometry (ISAK) guidelines. Specific methodological details are provided in subsequent chapters. Particular mention is made of quality

assurance methods implemented to increase reliability and validity of anthropometric data.

Chapter 4 introduces Study One, comparing change in traditional and alternative anthropometric measures in an overweight/obese population, in order to identify the most discernible anthropometric measure of change. In the first instance the change in these measures were examined over a 4 month period to determine that the measures were changing significantly, thus permitting longitudinal investigation (Part A). Prior to comparing the change in traditional and alternative anthropometric measures over an extended time period of 12 months (Part B), consideration of the controversies surrounding the measurement of change and the issues associated with unit variation when analysing and comparing variables are discussed. This was an issue in Study One and various analysis methods are presented, and justification provided, for the choice of analysis used in the data analysis conducted in Part B.

Chapter 5 provides an overview of the relationship between obesity and psychological health, an area that is less clearly delineated in comparison to the medical co-morbidity of obesity that is readily apparent (Steinbeck, 2004). The chapter introduces the self-concept, focusing on the development of the multidimensional self-concept and more specifically, perceptions of the physical self that are thought to have important implications on psychological health (Carron et al., 2003). This is followed by a review of research examining the relationship between physical self-perceptions and body composition. Following the development of adequate instrumentation to assess physical self-perceptions, researchers have been able to establish links between physical self-perceptions and body composition; however this research has primarily focused on BMI, body mass and %BF. Subsequently, Study Two therefore, aimed to provide an understanding of the link between physical self-perceptions and alternative anthropometric measures.

Identifying an anthropometric measure that demonstrates a higher discernible change than other anthropometric measures would be of greater value if that measure could also be correlated with health risk factors, for example elements of metabolic syndrome (MetSyn). It is known that traditional measures of obesity correlate with some MetSyn markers, however whilst evidence of an association between characteristic somatotypes and some diseases and conditions exists, this is scarce and has not focused on MetSyn markers specifically. Therefore, in Chapter 6, Study Three examined the relationship between traditional or alternative anthropometric measures and MetSyn in an overweight/obese population, and the relationship between their associated changes over a 6 month period. A review of pertinent research in the area of MetSyn is provided and evaluation of the methodological procedures and instrumentation used for the collection of haematological data considered.

The contribution of the individual studies in line with the original research aims, along with the practical implications of the research findings is described in Chapter 7. Limitations of the body of work are considered and suggestions made for further research directions.

2. LITERATURE REVIEW

Using a hierarchical approach to searching for literature, as proposed by Strauss and Sackett (1998), various methods were used to obtain information such as searching databases of reviewed high quality literature, searching evidence based journals for review articles and routine searches of PubMed, Medline, Elsevier/Science Direct and other search engines. Search terms remained broad to ensure relevant studies were not missed and following key word searches backward and forward searching techniques, as discussed by Levy and Ellis (2006), were employed to obtain a wide literature background. A stepped approach to compiling material was utilised and literature summarised under broad categories. These categories were then analysed in order to identify appropriate sub-headings. Initial summaries were then re-examined and relevant sections incorporated into the review under the appropriate headings. As a consequence of this thematic organisational approach, the literature review is divided into three parts. The first part of the review provides a definition of obesity and details the prevalence of obesity in the UK and the aetiology of obesity. Following this a review of the techniques used to identify obesity and measure the composition of the human body, focusing on their strengths and limitations are discussed. Finally the consequences of obesity are reviewed, focusing primarily on the physiological and psychological consequences.

2.1 Obesity

2.1.1 Defining obesity

Overweight and obesity are both labels for ranges of body mass that are greater than what is generally considered healthy for a given height (Centre for Disease Control & Prevention, 2009). More specifically, obesity is defined as an excessively high amount of body fat or adipose tissue in relation to lean body mass (Foreyt & St.Jeor, 1997). A commonly used assessment of

obesity is the body mass index (BMI) (Carmichael, 1999), calculated by dividing a person’s body mass in kilograms by their height in metres squared (kg.m^{-2}). Consensus has been reached when defining obesity in adults, and is said to occur when a person’s BMI is $>30\text{kg.m}^{-2}$ as a result of them gaining weight to the point of seriously endangering their health (ACSM, 2000). A person with a BMI $>40\text{kg.m}^{-2}$ is considered to be severely or morbidly obese (Miller, 2004). Super-obesity, although not officially recognized as a weight category, has been arbitrarily defined as when an individual's actual body mass exceeds their estimated ideal body mass by 225%, or by more than 200 pounds (90.7kg), or a BMI of $>50 \text{ kg/m}^2$ (Raftopoulos et al., 2005). A summary of weight classification based on BMI, graded to indicate the degree of risk to health, is given in Table 2.1.

Table 2.1. Weight classification based on BMI (kg.m^{-2})

BMI (kg.m^{-2})	Description	Risk of co-morbidities
18.5-24.9	Healthy Weight	Average
25-29.9	Overweight	Increased
30-34.9	Grade I Obesity	Moderate
35-39.9	Grade II Obesity	Severe
>40	Grade III Morbid Obesity	Very severe

World Health Organisation (1997)

These BMI cut-off points, used by the Centre for Disease Control (CDC) and World Health Organisation (WHO) as the standard definitions of overweight and obesity, provide benchmarks for assessment. However, the risks of disease in all populations can increase progressively from lower BMI levels. Furthermore, the cut off points were derived primarily in European populations to correspond to risk thresholds for a wide range of chronic diseases and mortality (Razak et al., 2007).

There is ongoing debate as to whether these criteria for obesity and overweight are appropriate for non-European populations and despite

heterogeneity and widely varying disease risk and obesity prevalence in ethnic groups, ethnic-specific BMI cut-off points are not used in Europe (WHO expert consultation, 2004). The justification for this being, that ethnic-specific cut-off points for BMI are thought to increase confusion in health promotion, and disease prevention and management in the increasingly multicultural societies in Europe.

2.1.2 Prevalence of obesity

The impact of obesity is so diverse and extreme that it has led to it being regarded as one of the greatest public health problems of our time (Gill et al., 1999). In the year 2000, estimations of the prevalence of obesity in established market economies (Europe, USA, Canada, Australia etc.) suggested an average prevalence in the order of 15-20% (Seidell, 2000). It is expected that more recent estimates of 300 million obese people worldwide could double by year 2025 if no action is taken against this threat (Formiguera & Canton, 2004). Estimations of the percentage of men and women in England, who are classified as obese have increased from 13.6% and 16.9% in 1993, to 24% and 25% in 2008, respectively (Zaninotto et al., 2008; Health Survey for England;HSE, 2008). Figure 2.1 shows trends in obesity in England over the last decade (Rennie & Jebb, 2005).

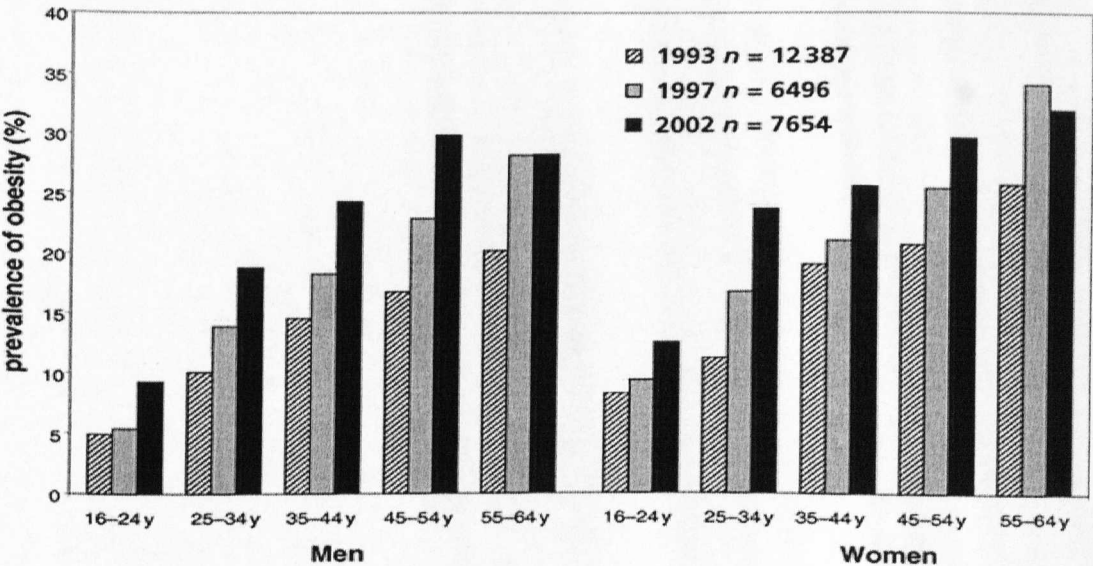


Figure 2.1. Secular trend in the prevalence of obesity (% with BMI>30kg.m⁻²) in Health Survey for England in men and women (Rennie & Jebb, 2005).

The largest increases in obesity prevalence are seen in the younger age groups with prevalence doubling in both men and women in the 25-34 years age group. Childhood obesity rates are also increasing rapidly in developed countries (Dehgan et al., 2005). For example from 1984-1998 Lobstein et al., (2003) documented a 12% increase in prevalence of obesity in children aged 7-11 years, rising from 8% to 20%. More recent estimations of childhood obesity indicate that 28% of boys and 36% of girls in the UK are now overweight or obese (International Obesity Task Force, 2009). By 2010 the number of overweight children across the European Union was estimated to reach 26 million, increase at an estimated rate of 1.3 million a year (International Obesity Task Force, 2006).

Data from the Health Survey for England (HSE) (2004) identifies the varying prevalence in obesity across ethnic groups, being particularly low in female Chinese and Bangladeshi communities (8%) and highest among women in Black African (38%), Black Caribbean (32%) and Pakistani (28%) groups. Black Caribbean and Irish men had the highest prevalence of obesity (25%). It should be noted that the HSE 2004 report used the same definition of overweight and obesity for ethnic groups as used for the general population as there are no agreed ethnicity specific BMI cut off points. The use of standard BMI cut off points in measuring obesity and overweight among certain ethnic groups is under debate, therefore the results of the HSE 2004 prevalence data of ethnic groups should be interpreted with caution.

2.1.3 Etiology of obesity

The etiology of obesity is regarded as a complex interaction of genetic, environmental, and behavioural factors (Aronne, 2002); it is not attributable to one specific factor (Donnellan, 2003). This is one reason why it is so difficult to treat (Rimmer, 1994). Support for the involvement of genetic factors in the development of obesity comes from studies of nuclear families, follow-ups of adopted children, and comparisons of monozygotic and dizygotic twins (Bray, 2003). However, despite the identification of several

clear endocrine abnormalities that cause obesity, they are rare and should be considered as part of the diagnostic process (British Nutrition Foundation, 1999). Furthermore, whatever the influence the genotype has on etiology of obesity, it is generally attenuated or exacerbated by non-genetic factors (Afridi & Kahn, 2004). Additionally, whilst some people are more genetically susceptible to weight gain than others, the genetics of the population have not changed significantly in the past 20 years, so the increase in obesity can be attributed to other non-genetic factors (National Audit Office, 2001).

Weight maintenance results from achieving a state of energy balance in which total energy intake from food is matched by total energy expenditure, composed primarily of resting metabolic rate, the thermic effect of feeding, and physical activity (Van Zant, 1992). An important, though simple concept of obesity, is that it results from an imbalance between energy intake and energy expenditure (Carmichael, 1999). Energy balance determines whether body fat increases, decreases, or remains the same (Brooks et al., 1996). Hill and Peters (1998) support this concept, suggesting that the current epidemic of obesity is caused largely by an environment that promotes excessive food intake and provides obstacles to physical activity. However, the upward trend for obesity in the UK appears to parallel an increase in physical activity. For example, statistics on physical activity in England, published by the HSE (2010) indicate that physical activity levels have increased among both men and women, with 39% of men and 29% of women meeting the recommended levels in 2008 (at least 30 minutes of moderate intensity activity at least 5 times a week), compared with 32% and 21% respectively in 1997. However, this means that 6 out of 10 men and 7 out of 10 women are still not meeting the recommended levels of physical activity. Furthermore, when examining physical activity levels achieved by overweight/obese individuals, these levels are lower than those achieved by their normal weight counterparts.

Table 2.2 highlights the reduction in activity levels with increasing BMI among adults in England. For example, in 2003, 44% of normal weight adult

males (BMI: 18.5-24.9kg.m⁻²) participated in recommended levels of physical activity, compared with just 16% of morbidly obese adult males (BMI: <40 kg.m⁻²).

Table 2.2. Adults (>16years) reaching recommended guidelines for physical activity levels by body mass index and gender in England, 2003.

	Percentage reaching recommended guidelines of activity*			
	Normal (18.5 – 24.9 kg.m ⁻²)	Overweight (25-29.9 kg.m ⁻²)	Obese excl. morbidly obese (30-39.9kg.m ⁻²)	Morbidly obese (>40kg.m ⁻²)
Men	44	37	31	16
Women	30	25	18	18

*30 minutes or more on at least 5 days a week
(Adapted from Health Survey for England, 2003)

To prevent weight gain or regain, the current recommended guidelines of physical activity may be insufficient for many individuals, particularly in today’s “obesogenic” environment (Saris et al., 2003). Research suggests that prevention of weight regain in formerly obese individuals requires 60-90minutes of moderate intensity activity or lesser amounts of vigorous intensity activity per day, five days a week (ACSM, 2000). Thus the above results indicate that whilst physical activity levels have increased over the last decade, the level of physical activity reached by individuals may not be of sufficient level to maintain a healthy weight and prevent the upward trend in obesity

Many factors contribute to today’s obesogenic environment and obesity trends continue to increase dramatically, in part, as an unintended consequence of the economic, social, and technological advances that have contributed to unhealthy dietary habits and sedentary behaviour during the past several decades (Aronne, 2002). For example, the increasing availability of energy dense foods, the substitution of physically active leisure with sedentary pastimes such as television, computers and the internet, and the decline of walking as a mode of transport, are all factors that have contributed to the increasing prevalence of obesity (Donnellan, 2000). This

increasing incidence of obesity is a major health concern, since it is an important risk factor for numerous life-threatening and debilitating diseases (Carmichael, 1999).

2.2 Measurement of obesity

2.2.1 Current indices of obesity

As simple as the definition of obesity appears, establishing the best technique to measure obesity has been a matter of dispute (Franzosi, 2006, James, 2005). Since the 1950s it has been recognized that fat distribution, independent of overall obesity, is associated with metabolic disturbances and increased disease risk (Snijder et al., 2006). Consequently, because of its importance to health, body composition is commonly investigated in epidemiological, clinical, and population studies (Moreno et al., 2003). Methods include measurement of body mass, body mass index (BMI), waist circumference (WC), waist-hip-ratio (WHR), skinfold thickness and somatotype (Carmichael, 1999; Crawford, 2002).

2.2.1.1 Weight-related parameters

Weight-related parameters, such as body mass and BMI, are the most commonly used methods to determine obesity status and measure success within weight management programmes (Carmichael, 1999). Body mass is an easy, precise measure, and values greater than 120 percent of the average expected for height and sex have been considered indicative of obesity in many studies (Rowland, 1990). However, despite the ease and simplicity of this method, it is impossible to determine accurately if a fluctuation in body mass is due to a change in muscle, body water, or fat (Brooks et al., 2001). Furthermore, using this method to evaluate responses to dietary-exercise treatment has the potential to result in false conclusions regarding success and change in health status, because significant fat can

be lost and muscle mass gained with little change in overall body mass (Rowland, 1990).

BMI has become the standard by which a person's relative weight is measured (Crawford, 2002) and its use as a standard population level assessment is advantageous due to its simplicity (Brooks et al., 2001). The BMI categorisation system, now used internationally, has made it easy to estimate and compare the prevalence of the overweight and the obese in populations (Webb, 2000). However, these reference ranges, recommended by the WHO and used to determine level of risk, are based on studies using data from healthy adult Caucasians (WHO, 1997). This limits their application to populations and individuals of different ethnic origins and health status. Increases in average height and body size over generations also limit the application of universal BMI cut-offs to the current population (Cook et al., 2005), particularly in the extremities of the height scale where BMI's intrinsic mathematical limitations become more evident (Ricardo & Araujo, 2002). Furthermore, BMI does not differentiate between the non-fat and fat masses or accurately represent an individual's health status (Burkhauser & Cawley, 2008; Garcia et al., 2005; Norton & Olds, 1996), nor does it account for factors such as size of body frame, proportion of lean mass, gender and age (O'Meara et al., 2001). Additionally it is not sensitive enough to recognize small yet clinically significant weight losses (Cook et al., 2005). Moreover, Blair and LaMonte (2006), point out that much of the extant prospective data indicate that there is little difference in risk across a very wide range of BMI values, suggesting it is fat distribution that is important in terms of health risk. Consequently, BMI is best viewed as a measure of heaviness (Norton & Olds, 1996).

The specificity and adequacy of weight related parameters is controversial because they do not allow a precise assessment of body composition (Garcia et al., 2005). The body is composed of two elements: lean body tissue (i.e. muscles, organs, bones and blood) and body fat or adipose tissue (Heymsfield et al., 1990). The proportion of these two components in the

body is called body composition (Bean, 1996). Both the total amount of body fat and the way in which fat is regionally distributed in the body are principal risk factors for the high rate of chronic disease in individuals who are obese (Heyward & Wagner, 2004). Consequently, body composition is commonly investigated in epidemiological, clinical, and population studies (Moreno et al., 2003). Reliable methods for measurement of body fat and fat distribution are therefore important.

2.2.1.2 Waist circumference/waist-hip-ratio

Much research has suggested that, to classify overweight individuals accurately with respect to health risks, both BMI and an indicator of fat distribution must be considered (Bray, 2003). The health risks of obesity are compounded by the influence of fat which is distributed around the waist (Bray, 2003; Chan et al., 2003; Webb, 2000). For this reason, WC and WHR are commonly used as an assessment of fat distribution and the risks associated with obesity (Dalton et al., 2003; Onat et al., 2004). Whilst the measurements are less direct methods of assessing body fat status compared to more advanced techniques such as dual-energy x-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) (Sharp, 1995), they are simple and useful tools for gauging the priority that should be attached to weight reduction in different individuals (Webb, 2000).

A report by the WHO suggests that increased obesity-related health risks are present when the WC exceeds 94 cm (37 inches) in men, or 80 cm (32 inches) in women (WHO, 1997). The higher the WC, the more substantial this risk becomes, as documented by Lean et al. (1995) who found that a WC of 102 cm in men and 88cm in women corresponded to a BMI of 30 kg.m⁻². Lean et al. (1995) recommended that men with WC ≤94 cm and women with WC ≤80 cm should gain no further weight, and men with WC >102 cm and women with WC >88 cm should reduce their weight. These simple cut-off points may be helpful for the classification of Caucasian adults, however in other ethnic groups or older age groups they are less appropriate

(Snijder et al., 2006) as different ethnicities have different body builds and proportions and research indicates that adipose tissue distribution for a given WC is altered substantially by age (Kuk et al., 2005).

It is important to acknowledge the numerous measurement protocols available for the measurement of WC, which may contribute to measurement error when used interchangeably. For example, a literature review by Wang et al., (2003) identified 14 different descriptions for the measurement of WC, and organised these into four groups defined by specific anatomical landmarks; immediately below the lowest rib; at the narrowest waist; midpoint between the lowest rib and the iliac crest; and immediately above the iliac crest. When comparing the magnitude and reliability of WC measured at these 4 sites, reproducibility for all sites was high (intraclass correlation (r) values >0.99), however the sites significantly differed in magnitude from each other, in a sex-dependent manner (Wang et al., 2003). These differences could have important implications in clinical practice and within research utilising both WC and WHR, which incorporates a WC measure. The issue of varying measurement protocols is not restricted to WC alone. For example, numerous protocols for the measurement of stature also exist, including stretched and unstretched techniques (Tillmann & Clayton, 2001).

WHR is a simple indicator of body fat distribution. It is the circumference of the body at the waist divided by the circumference around the hips (Webb, 2000). Cut-off scores for increased health risk have ranged from 0.91 to 1.0 for men and from 0.80 to 0.91 for women (Norton & Olds, 1996). A value greater than the recommended thresholds, indicates excess fat in the abdomen and a higher health risk (Bean, 1996). In comparison to WHR, WC alone is a more crude measurement for abdominal obesity, whereas WHR takes advantage of a reference of body size, hip circumference. Dalton et al., (2003) in a comparison of the use of BMI, WC and WHR as predictors of cardiovascular disease (CVD) risk factors also concluded that WHR is the most useful measure of obesity in terms of predicting CVD risk. Furthermore,

in a large cross-sectional study of 313 men and 382 women, Seidell et al (2001) showed that after adjusting for BMI and age, WHR was highly correlated with visceral fat but not subcutaneous fat, with WC highly correlated with both visceral and subcutaneous fat.

Visceral fat volume has been found to be the strongest independent predictor of metabolic risk in men and women matched for total body fat but differing in visceral fat mass (Fried & Ross, 2004). In a large, diverse population with a broad age range Elsayed et al., (2008) identified an association between WHR and visceral fat; however no association was evident between WHR and subcutaneous fat. This may explain why WHR is a better predictor of health outcomes than WC. In contrast, studies by Kamel et al. (1999), who compared WC measures against DXA measures, and Onat et al. (2004) who compared a range of anthropometric indices against CT, both suggest that it is WC that is more strongly associated with visceral fat. Despite this, research indicates that hip circumference is inversely associated with the development of cardio-metabolic risk factors and CVD (Koning et al., 2007), with weaker associations observed between type II diabetes mellitus (T2DM), CVD and WC (Snijder et al., 2006). Table 2.3 summarises some of the strengths and limitations of WHR and WC.

Table 2.3. Strengths and limitations of WHR and WC

	WHR	WC
Applicability in large populations studies	Very high ¹	Very high ¹
Capability to detect change	Poor due to validity of serial measurements and genetic component to WHR ^{2/3}	Preferred index in comparison to WHR ³
Predictor of health outcomes	Strong association with cardio-vascular risk factors ⁴	Weaker association with T2DM and cardio-vascular risk factors ⁵
Predictor of subcutaneous/ visceral fat	Association with visceral fat ⁶	Association with visceral fat and subcutaneous fat ^{6/7}

¹Snijder et al. (2006); ²Dalton et al. (2003); ³Gibson, (2005); ⁴Koning et al. (2007); ⁵Snijder et al. (2007); ⁶Han et al.(2006); ⁷Seidell et al. (2000)

The research discussed above indicates small differences in the discriminatory capabilities of WC and WHR, thus from a clinical perspective, it may not be possible to advocate one measure over the other. However, as a tool to monitor change in body composition, WC may be more useful as it is not confounded by serial measurements.

2.2.2 Assessing body composition

2.2.2.1 Levels of human body composition

Body composition is the common name for the methodology of dividing the body into different compartments (Heymsfield et al., 1990). It is common to explain human structure in terms of increasing organizational complexity ranging from atoms and molecules to the anatomical, described as a hierarchy of cell, tissue, organ, system and organism (Hawes & Martin, 2001) (Fig.2.2). Each level has clearly defined components and the sum of components is equal to the total body weight (Salmi, 2003). Knowledge of the interrelationship of constituents within a given level or between levels is also important, and may be useful for estimating the size of a particular compartment (Hawes & Martin, 2001).

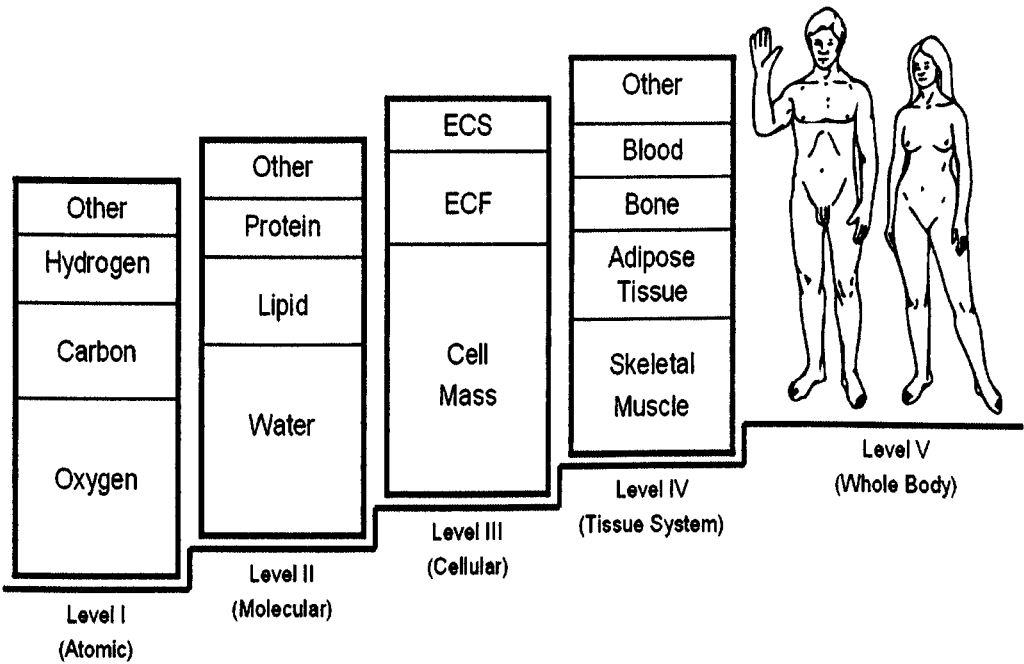


Figure 2.2. The five levels of human body composition according to Wang et al. (1992).
ECS – extracellular solid, ECF – extracellular fluid

Approximately 50 elements comprise body composition at the atomic level. One element, oxygen, constitutes >60% of total body mass, with the addition of carbon, hydrogen, nitrogen, calcium and phosphorus accounting for >90% of total body mass. The remaining 44 elements comprising less than 2% of total body mass (Wang et al., 1992). At the molecular level of organisation more than 100,000 chemical compounds can be reduced to five main chemical groupings; lipid, water, protein, carbohydrate and mineral (Hawes & Martin, 2001). At the cellular level the body is divided into cell mass, extracellular fluid (ECF) and extracellular solids (ECS) and at the fourth level of organisation (tissue system), these components are further organised into tissues, organs, and systems (Wang et al., 1992). At the whole body level the body is considered as a single unit representing body size, shape, density, surface area and external characteristics (Hawes & Martin, 2001).

2.2.2.2 Measurement techniques

Due to the numerous terms used in body composition literature, prior to discussing measurement techniques used to measure body composition it is first necessary to define commonly used terminology (Table 2.4).

Table 2.4. Body composition terminology

Term	Definition
Body fat mass	Quantity of triglyceride fat in the body
Adipose tissue mass	Fat plus supporting cellular and extra-cellular tissues (pure fat 83%, protein 2%, water 15%)
Lean body mass	Non-adipose tissue body mass (body cell mass plus extracellular water and extracellular solids)
Fat-free mass	Lean body mass plus non-fat component of adipose tissue
Body cell mass	Cellular components of the body including extracellular water (lean body mass minus extracellular water and extracellular solids)
Extracellular solids	Total body bone mineral (skeleton) plus fascia and cartilage (skeleton 85%, others 15%)

Morgan & Madden (1996)

The quantity of triglyceride fat in the body is defined as body fat mass, whereas adipose tissue is defined as fat mass together with its' supporting cellular and extracellular structures (Morgan & Madden, 1996). Fat-free mass is the sum of all body tissues minus all body fat (essential and non-essential). The lean body mass (LBM) is the FFM with the inclusion of essential (non-adipose) lipids (Hawes & Martin, 2001); however LBM is sometimes used erroneously as a synonym for FFM. The cellular components of the body, including intracellular water are defined as body cell mass and extracellular solids consists of total body bone mineral, that is the skeleton.

As direct measurement of body composition *in vivo* is not possible in humans, a series of indirect estimations of body constituents have been developed. Most interest has been directed at the two-compartment (2-C) model (molecular level) that suggests total body weight is the sum of two categories: fat mass and fat-free mass (Ellis, 2000). By assuming that density values of fat-free mass, potassium, and water are stabilized and constant, estimates of absolute and relative body fat can be made (Hawes & Martin, 2001). The assumption of a constant composition of fat free mass is central to the 2C-model and methods, however many clinical studies have demonstrated that the 2-C model has limited applicability with regard to its use in different ages, gender and ethnic groups.

Recently there has been a move away from the 2-C model toward three (3-C) or four-component (4-C) models (Brodie et al., 2005). These models partition body weight into three or four body weight fractions, respectively (Heymsfield et al., 1990). For example, 3-C models control for inter-individual variation in fat-free mass by partitioning weight in to fat mass, total body water and fat-free dry mass (Withers et al., 1998). 4-C models divide body weight into fat mass and the constituents of fat-free mass, namely the aqueous, protein, and mineral fractions (Heymsfield et al., 1990). As more components are measured in these models, fewer assumptions are required and these are regarded as superior to 2-C methods. However, they are more

difficult to perform, in terms of cost and expertise (Norgan, 2005) and the use of 2-C models are still considered valuable in most cases when assessing fat and fat free ratios against total body weight (Salmi, 2003).

Many methods are available to estimate total body fat or adipose tissue, with different levels of accuracy, practicality, and cost (Sardinha & Teixeira, 2005). The earliest and probably the most frequently used 2-C model is based on the measurement of total body density, most commonly using hydrodensitometry or underwater weighing (Ellis, 2000). These are generally considered criterion reference methods (Garcia, 2005). Other methods used to obtain reference measures of body composition include computerized tomography (CT), MRI, neutron activation analysis and DXA (Heyward, 2001; Pontiroli et al., 2002). Because these reference methods do not measure body composition directly, but rather predict it from measurement of body properties, none can be singled out as a 'gold standard' for *in vivo* body composition assessment (Heyward, 1996). Direct analysis of body composition can only be carried out by chemical analysis of cadavers (Hosking et al., 2006). Thus all techniques suffer from methodological error when collecting raw data, and error in the assumptions by which raw data are converted to final values (Wells & Fewtrell, 2006).

Furthermore because of the costs of the reference methods in terms of time and money, together with the need for tester expertise (Snijder et al., 2006) many are not practical in epidemiological studies or for routine clinical use (Table 2.5). Consequently there are no normative data on body fat content that can be used as clinical or surveillance tools (Prentice & Jebb, 2001). Whilst techniques such as bioelectrical impedance analysis (BIA) and DXA do not require as much training as skinfold and circumference to achieve reliable results, these techniques suffer from practical and methodological limitations. DXA instrumentation is expensive and cannot be easily transported to test sites in large-scale intervention and epidemiology projects (Van Loan, 1997). BIA, whilst inexpensive and readily available to the public, uses population specific prediction formulas, and prediction errors may be

too large for valid individual assessment in clinical situations (Deurenberg, 1996).

At the whole-body level of body composition, other anthropometric measures used to assess the size, composition and proportions of body segments include skinfold thicknesses, circumferences, skeletal breadths and segment lengths (Heyward & Wagner, 2004). These measures have been adopted as substitute measurement methods in clinical and public health works (Heyward & Wagner, 2004; Batisita, 2004) as they are applicable to large samples and can provide national estimations and data for the analysis of secular changes in representative samples (Loan, 1997; Bellisari & Roche, 2004).

Table 2.5. Capability of different body fat measurements to estimate total body fat and fat distribution (reproduced from Snijder et al., 2006).

Method	Capability measuring total body fat	Capability measuring fat distribution	Applicability in large population studies
CT	Moderate	Very High	Low
MRI	High	Very High	Low
DXA	Very High	High	Moderate
Densitometry	Very High	Very Low	Low
Dilution Techniques	High	Very Low	Moderate
BIA	Moderate	Very Low	High
BMI	Moderate	Very Low	Very High
WHR, HC, WHR, SAG-D	Low	High	Very High
Skinfolds	Moderate	Moderate	High

Laboratory measurements: CT, computed tomography; MRI, magnetic resonance imaging; DXA, dual energy x-ray absorptiometry.

Field measurements: BIA, bioelectrical impedance analysis; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; SAG-D, sagittal abdominal diameter

Determining the thickness of the skin at specific sites is the simplest and by far the most widely used method of gaining useful estimations of body fat (Sharp, 1995). Together with girth measurements, they are useful for monitoring body composition changes over a period of time (Bean, 1996). The skinfold is a measure of the thickness of two layers of skin and the

underlying subcutaneous fat (Heyward & Wagner, 2004). It is assumed that determination of skinfold thickness by calipers provides a localized estimate of subcutaneous fat, which has been used as an index of total body adiposity or relative body fatness (Rowland, 1990). The thickness of the skinfold at various defined body sites is measured and the sum of these skinfolds is determined (Webb, 2000).

Skinfold measurements can be used to predict total body fat using any one of a number of predictive equations available in the literature (Norton & Olds, 1996). It is important when equations are applied to estimate the total body fat of an individual, that they are derived from a similar population, as using an inappropriate equation may produce systematic prediction error in estimating body composition (Brooks et al., 1996). Factors such as age, gender, ethnicity, level of body fatness, and physical activity level should be considered (Heyward & Wagner, 2004). Many current equations show a lack of accuracy in predicting body composition in overweight and obese populations (Sartorio et al., 2000) and there is a scarcity of equations developed specifically to predict %BF in participants with a BMI $>34 \text{ kg.m}^{-2}$ (Horie et al., 2008).

Whilst there is a substantial literature available on the subject of skinfold measurement, there are known limitations to the measurement of skinfolds, some of which tend to be accentuated in obese subjects (Van Loan, 1997). However, the accuracy of this method can be improved through multiple measurements by a single, experienced observer (Norton & Olds, 1996) and when used appropriately the tools of anthropometry can provide valid results (Stewart et al., 2003). Furthermore the development of an accreditation scheme developed by the International Society for the Advancement of Kinanthropometry (ISAK) has contributed to the precision and reliability of results obtained through this method.

2.2.2.3 ISAK

Anthropometry, like any other area of science, depends upon adherence to the particular rules of measurement as determined by national and international standards bodies (Norton & Olds, 1996). There have previously been attempts to standardise anthropometric measures, however these did not achieve international recognition (Stewart et al., 2003). ISAK has strived to develop standardised protocols and, following a successful model pioneered in Australia, formulated an accreditation scheme recognising four levels of technical expertise (Stewart et al., 2003). These include: technician (restricted profile), technician (full profile), instructor and criterion anthropometrist (Appendix 1). The measurements included in full and restricted profiles are detailed in Appendix 2.

The need for an ISAK anthropometry accreditation scheme evolved from recognition of the concern for and the need to: standardise techniques and applications, increase the competencies of individuals involved in kinanthropometry; and establish means whereby professionals within the field and the public consumer can recognise professional competence at different levels (Australian Institute of Sport, 2006). The ISAK accreditation system for anthropometrists has operated since 1996 with the aim of establishing a global standard for anthropometry. Over 3000 anthropometrists from 49 countries have been accredited in anthropometric measurement techniques under this scheme (ISAK, n.d.). Adoption of these standards allows standardisation of measurements between participants and of repeated measurements on the same participants. Furthermore, it allows comparisons to be made locally, nationally and internationally between sample groups.

2.2.2.4 Levels of validation

In addition to the five levels of organisation (Fig.2.2), there are three levels of validation in body composition. The validity of a method is the extent to which it accurately measures a quantity of which the true value is known (Hawes & Martin, 2005). Table 2.6 orders body composition methods into levels of validity. This distinguishes components that are measured from those where the component of interest is derived by transformation of a measured property of the body on the basis of various biological and technical assumptions (Norgan, 2005).

Table 2.6. Levels of validation of body composition methods (Hawes & Martin, 2001).

Method	Validation Level	Approach
Dissection (cadaver studies)	I	Direct measurement of body fat by dissection of subject
Densitometry CT MRI DXA	II	Indirect measurement, assumptions based on qualitative measures
Anthropometry BIA	III	Doubly indirect, regressed against a level II method

Laboratory measurements: CT, computed tomography; MRI, magnetic resonance imaging; DXA, dual energy x-ray absorptiometry;BIA, bioelectrical impedance analysis.

Body composition analysis is unusual in that only cadaver dissection (level I validation) can give truly valid measures (Hawes & Martin, 2001). Level II measures are indirect (i.e. some quantity other than fat is measured to enable an estimation of fat mass from the measured quantity) and Level III measures are doubly indirect as they are derived by applying a regression equation against a level II method, almost always densitometry or in recent years DXA-based equations (Hawes & Martin, 2001)

Many studies have compared the validity of these body composition analysis techniques in normal weight, healthy populations (Maddalozzo et al., 2002; Sun et al., 2006), ageing populations (Reilly et al., 1994; Chen et al., 2007) and athletic populations (Utter et al., 2005; Silva et al., 2006). However, the ability of most methods to measure change is less than the measurement of absolute values (Norgan, 2005) and there is little research comparing body composition methods over a period of weight loss (Frisard et al., 2005). Studies that have used overweight or obese populations and investigated the application of various body composition methods during weight loss include those by; Frisard et al. (2005), Kim et al. (2005), Ritz et al. (2007) and Weyers et al., (2002).

DXA and air displacement plethysmography (ADP) have been found to be sensitive enough to measure moderate body composition changes with weight loss (Weyers et al., 2002), however these methods are expensive, limiting their applicability for routine use (Van Loan, 1997). Evans et al., (1999) compared estimates of change in %BF from DXA (level II measure), skinfold thickness, BIA and BMI (level III measures), with estimates from a 4-C model in a group of obese women (n=27). Changes in %BF averaged $2.1 \pm 1.0\%$, $-1.2 \pm 1.4\%$, and $-2.4 \pm 1.6\%$ in control, diet only, and aerobic exercise groups, respectively. Results indicated that errors in estimation of the change in %BF were comparable in all techniques when compared with a 4-C model (range ± 2.0 - 2.4% of body mass). Additionally the type of weight loss intervention (diet or aerobic exercise) did not affect the magnitude of error in the assessment methods.

Frisard et al., (2005) assessed body composition using DXA (level II measure), BIA and ADP (level III measures) before and after a 6 month weight loss program in overweight adults (n=56). BIA and ADP under- and over-estimated %BF, respectively, compared with DXA. However, correlation coefficients of both methods were relatively high compared with DXA for measuring change in body composition and all were found to be sensitive enough to detect changes with weight loss (r^2 range 0.57-0.63).

The results of these two studies suggest that skinfold thickness and BIA may be valid techniques in overweight/obese populations.

In contrast, a study that compared the use of skinfold thickness, BIA and DXA in non-obese participants and obese participants, found skinfold thickness and BIA to be preferable techniques to analyse body composition in non-obese participants, with DXA considered the method of choice in obese patient monitoring (Erslecan et al., 2000). Furthermore, Kim et al., (2005) found significant discrepancies at baseline %BF estimated by DXA and BIA, with the lack of agreement being more pronounced in larger or more obese persons. This suggests that BIA is not as valid in this population.

In light of the conflicting research regarding the validity of body composition analysis techniques, Hawes & Martin (2001) suggest that the best use of body composition techniques is for repeated measures in the same individuals over a period of time. Furthermore, a study by Puller et al., (1992) suggests that skinfold thickness estimation equations proved to be as good as 3-C models and DXA in estimating group mean fatness and the best of the field techniques for individual estimates of fatness.

2.2.3 Somatotyping

Various systems for classifying physique and assessing the body shape and composition of individuals have been proposed over the centuries (Carter & Heath, 2005). This has led to the system called “somatotyping” as proposed by Sheldon (1940), and subsequently modified by others, notably Parnell (1985) and Heath and Carter (1967). A somatotype is a quantified expression or description of the present morphological conformation of the human body (Duquet & Carter, 2009). Classification of human body types can be attributed as far back as Hippocrates, though a systematic approach was not implemented until the twentieth century. The tri-polar somatotype devised by Sheldon was later revised by Heath and Carter in the 1960s into a phenotypic method based on calculations made up of ten anthropometric

measurements. The Heath-Carter method of somatotyping is now the most universally applied (Kalichman & Kobylansky, 2007) and can be obtained in three ways; 1) the photoscopic somatotype; 2) the anthropometric somatotype; and 3) the anthropometric plus photoscopic somatotype.

The photoscopic somatotype is based on visual inspection of the subject, or photographs taken according to standardised instructions (preferably a front, a side and a back view) (Carter & Heath, 2005). Practice and experience is required to make consistently valid and reliable ratings using the photoscopic method and few people get the opportunity to become criterion raters using photographs (Norton & Olds, 1996).

Ten anthropometric measures are needed to calculate the anthropometric somatotype: stretch stature, body mass, four skinfolds (triceps, subscapular, supraspinale, medial calf), two bone breadths (biepicondylar humerus and femur), and two limb girths (arm flexed and tensed, calf). The instruments needed to measure these dimensions (Appendix 3) are portable and relatively inexpensive (Bellisari & Roche, 2005) thus enhancing its applicability in laboratory and field based studies. Furthermore, providing measurements are taken by proficient technicians, these anthropometric dimensions can provide an accurate, detailed summary of individual's body composition (Norton, & Olds, 1996). Anthropometric measurement followed by photoscopic evaluation is considered the criterion method (Ducquet & Carter, 2009). In the absence of photographs, the anthropometric somatotype provides the best estimate of a criterion somatotype (Carter & Heath, 2005) and is the method that will be applied for identifying somatotype within this investigation.

2.2.3.1 Somatotype rating

The somatotype is expressed as a numeral on a continuous scale that theoretically starts at zero and has no upper limit. It summarises the physique as a unified whole, independent of size, by combining the appraisal

of adiposity, musculoskeletal robustness and linearity, into a three-number rating (Duquet & Carter, 2001). Ratings of ½ to 2 ½ are considered to be low, 3 to 5 as moderate, 5 ½ to 7 ½ and above as very high (Carter & Marfell-Jones, 1994). The numerals are always recorded in the same order, representing endomorphy, mesomorphy, and ectomorphy components respectively (Carter & Marfell-Jones, 1994).

2.2.3.2 Endomorphy

Endomorphy refers to relative fatness of the body (Norton & Olds, 1996). It also describes corresponding physical aspects such as roundness of the body, softness of the contours, relative volume of the abdominal trunk, and distally tapering of the limbs (Duquet & Carter, 2009). Body mass tends to be centred in the lower abdomen and hip region, giving a pear-shaped appearance (Fig.2.3A), and endomorphs tend to have relatively low metabolic rates and gain weight faster compared to the ectomorphic or slender person (Grandjean, 1999).

Both genetics and environment influence the presence of phenotypic somatotype (Carter & Heath, 2005). For example, Spalding et al., (2007) report that adipocyte number is a major determinant for fat mass in adults and that this number stays constant, even after marked weight loss in both lean and obese individuals. This indicates that the number of adipocytes is set during childhood and adolescence and this could provide partial explanation for high endomorphy ratings. However, in order to create an energy deficit that promotes weight loss and a reduction in fat mass, energy intake needs to be reduced and/or energy expenditure needs to be increased (Stiegler & Cunliffe, 2006). Individuals with excess body mass may find it difficult to sustain the physical activity levels required to create an effective energy deficit, thus exacerbating their endomorphic state.

2.2.3.3 Mesomorphy

Mesomorphy refers to the relative musculo-skeletal robustness of the body (Norton & Olds, 1996). It also describes corresponding physical aspects such as the apparent robustness of the body in terms of muscle or bone, the relative volume of the thoracic trunk, and the possibly hidden muscle bulk (Fig.2.3B). Predominant mesomorphs have little or no trouble with body weight fluctuations and are stronger and more robust than ectomorphs and endomorphs (Duquet & Carter, 2001).

Again a genetic influence may play a part in mesomorphy ratings as to a large extent testosterone secretions determine the rating of this component (Carter & Ackland, 2009), with high testosterone levels associated with significant gains in fat-free mass, muscle size and strength (Bhasin et al., 2001). However, lifestyle activity may also contribute to degree of mesomorphy, for example those in active professions, or who participate in regular physical activity may become more muscular in comparison to individuals in less active professions, or who do not train.

2.2.3.4 Ectomorphy

Ectomorphy refers to the relative slenderness of the body (Norton & Olds, 1996). It also describes corresponding physical aspects such as the apparent linearity of the body or fragility of the limbs, in absences of any bulk, be it muscle, fat or other tissues (Duquet & Carter, 2001). Ectomorphs are small framed, low fat individuals (Fig.2.3C).

The factors which prevent normal weight gain and muscular development are appetite and metabolism. Relative resting metabolic rate is increased in individuals with low fat and increased lean mass, thus making it difficult for ectomorphs to gain weight and muscle (Grandjean, 1999). Ectomorphic characteristics may also be a consequence of individuals' behaviours such as low caloric intake.

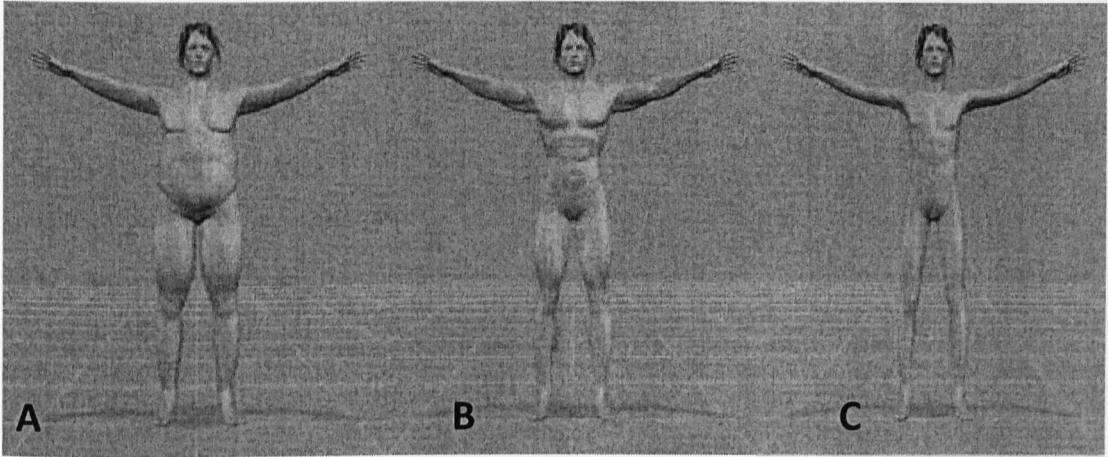


Figure 2.3. Bodies displaying endomorphic (A), mesomorphic (B), and ectomorphic (C) characteristics (bodytypes.wordpress.com, 2008).

Table 2.7 on the following page describes the various characteristics associated with the different ratings for each somatotype sub-component.

Table 2.7. Characteristics associated with different ratings for endomorphy, mesomorphy and ectomorphy (Norton & Olds, 1996).

Endomorphy Rating Scale and Characteristics (relative fatness)																
1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9+
Low relative fatness; little subcutaneous fat; muscle and bone outlines visible				Moderate relative fatness; subcutaneous fat covers muscle and bone, softer appearance								High relative fatness; thick subcutaneous fat, increased storage of fat in abdomen				Extremely high relative fatness; very thick subcutaneous fat
Mesomorphy Rating Scale and Characteristics (musculo-skeletal robustness relative to height)																
1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9+
Low relative musculo-skeletal development; narrow skeletal diameters; narrow muscle diameters, small joints in limbs				Moderate relative musculo-skeletal development; increased muscle bulk and thicker bones and joints					High relative musculo-skeletal development; wide skeletal diameters; bulky muscles; large joints				Extremely high relative musculo-skeletal development; very bulky muscles; very wide skeleton and joints			
Ectomorphy Rating Scale and Characteristics (relative linearity)																
1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9+
Low relative linearity; great bulk per unit of height; round like a ball; relatively bulky limbs				Moderate relative linearity; less bulk per unit of height; more stretched out					High relative linearity; little bulk per unit of height				Extremely high relative linearity; very stretched-out; narrow' minimal bulk per unit			

33

2.3 Importance of monitoring body composition

In both the prevention and treatment of obesity, many strategies such as dietary interventions, behavioural therapy and the promotion of physical activity are considered important (Cooper & Fairburn, 2001). However, methods used to report weight loss have been multiple and occasionally contentious (Deitel et al., 2007). Weight loss and weight management programme effectiveness is often based solely on participant weight change (Roux et al., 2004). However focusing on weight loss alone can be misleading as it does not account for individual variability (Sargent et al., 2000). In a study of the effects of exercise on weight loss (Fig.2.4) by Pavlou et al., (1985), 72 obese males were randomly assigned to a weight loss program involving exercise or no exercise. The advantage of exercise would appear modest if only weight change (kg) was considered. However, body fat analysis revealed that the exercise group lost 11.2 ± 1.5 kg fat vs. only 5.2 ± 1.6 kg in the non-exercise group ($p < 0.06$).

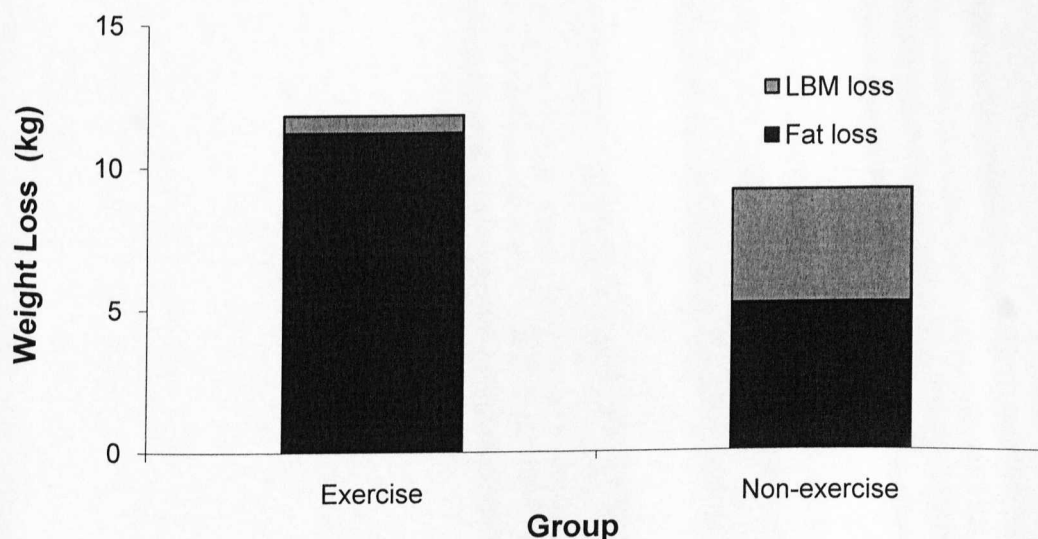


Figure 2.4. Effect of exercise on composition of weight loss (Pavlou et al., 1985).

In a meta-analysis of resistance and aerobic exercise programs in weight-maintenance regimes, Prentice & Jebb (2001) further highlight the

importance of considering body composition. They found that changes in body weight led to misleading impressions about underlying changes in body fat. This was particularly evident with resistance exercise that tends to build muscle mass. For example, Figure 2.5 indicates that the assumed change in body fat (simply derived as 75% of weight loss) in the resistance group was 0.1kg increase. However, body composition evaluation showed that the actual change (directly measured fat loss) was a decrease of over 2kg.

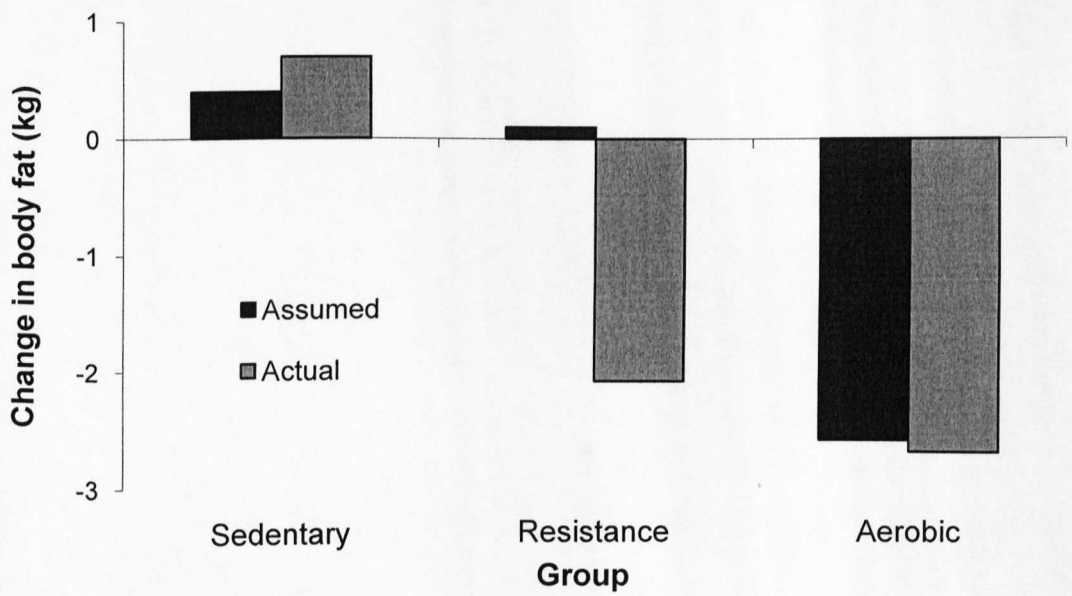


Figure 2.5. Assumed vs. actual changes in body fat after resistance or aerobic exercise (Prentice & Jebb, 2001).

In a comprehensive review of the influence of physical activity on abdominal fat, Kay & Singh (2006) systematically evaluated 19 randomised controlled trials and 8 non randomised controlled trials. They cited the most dramatic average decreases in visceral fat of 48% and 44%, in studies by Donnelly et al., (2003) and Pochlman et al., (2000) respectively. These decreases occurred in the absence of change in body mass. Furthermore, a review of pre-treatment predictors of weight control conducted by Teixeira et al., (2005) highlight an exclusive or excessive focus on weight as an outcome, as a limitation of current research. Moreover, they suggest that where possible, body composition should be accounted for if the analytical method used is sensitive to intra-individual change.

2.4 Obesity and its consequences

Obesity leads to much human suffering by contributing to chronic disease and premature mortality; it also entails a substantial cost to the National Health Service (NHS) and to the wider economy (National Audit Office, 2001). There is also a major social and societal cost that is difficult to measure (Lean, 1998).

2.4.1 Financial consequences of obesity

The problem of obesity has, until recently, remained un-addressed as a public health issue (Carlisle, 1998) and the relationship between BMI and future healthcare costs has received little attention (Thompson et al., 2001). This issue is of increasing importance as the numbers affected by obesity and the associated diseases are ever increasing and the countries' health services may be unable to cope in the future (Carlisle, 1998). A report by the National Audit Office (2001) highlighted the first authoritative estimate of the cost and consequences of obesity in England, providing a conservative estimate of the cost of treatment of obesity to the NHS at £1.5 billion a year in 1998. In 2002, the direct cost of treating obesity was estimated at between £45.8 and £49.0 million and between £945 million and £1,075 million for treating the consequences of obesity (Allender & Rayner, 2007). By 2010 obesity and its consequences are expected to cost the British economy more than £3.6 billion a year. Including all people who are overweight this cost could rise to between £6.6 and £7.4 billion (Donnellan, 2003), and with the addition of the wider cost to the economy in lower productivity and reduced output, this could rise by a further £2.1 billion a year (National Institute for Clinical Excellence, 2003).

The estimated economic costs of obesity vary in different countries, at different times and depend on thresholds used to define obesity (British Nutrition Foundation, 1999). However, all available estimates conclude that

somewhere between 1 and 7% of total healthcare budgets are attributable to overweight and obesity, depending on the methods of analyses used (Lean, 1998). There are also large costs associated with the care of diseases attributed to obesity.

The use and cost of medications are markedly increased in the obese compared with non-obese patients, with studies estimating that of the health care expenses attributable to obesity in affluent countries, approximately 30% are pharmaceutical costs for treating obesity-related disorders (Gould et al., 2004). In 2008, almost 1280,000 prescription items were dispensed for the treatment of obesity compared with just over 127,000 prescriptions in 1999 (an increase of 900%) (NHS, 2010). In a retrospective cohort study of the relationship between obesity and future health care costs, Thompson et al., (2001) found that individuals with BMI ≥ 30 had 36% higher annual healthcare costs, including 105% higher pharmacy costs and 39% higher costs of primary-care visits than their normal weight counterparts. Whilst these findings suggest that future healthcare costs are higher for persons who are overweight, the study limitations should be considered. The use of self-reported height and weight used in the study (Brener et al., 2003) has its limitations and furthermore, only 56% of those contacted responded to the mail survey that was used to identify the study cohort. Therefore the impact of possible response bias on the findings is unknown (Thompson et al., 2001).

It is evident from the data discussed above that the financial costs of obesity are high and are continuing to rise as the prevalence of obesity increases. Without intervention the financial costs of obesity could have serious implications on the NHS; however there is a need for more prospective studies to provide more accurate estimates of the costs of obesity. Furthermore, the cost-effectiveness of strategies to control obesity needs to be considered.

2.4.2 Physiological consequences of obesity

2.4.2.1 Obesity and co-morbidities

Numerous large scale epidemiological cohort studies have established that excess body weight (as established by BMI) is an important risk factor for a range of primary co-morbid conditions (Steinbeck, 2004). Each year, CVD is responsible for 37% of total deaths in the UK, and cancers a further 27% of deaths. It is accepted that at least part of the cause of these diseases are due to overweight and obesity (Allender & Rayner, 2007). Approximately 30,000 people die each year from co-morbid conditions which include heart disease, T2DM and hypertension (Brooks et al., 1996). Furthermore, health problems directly relating to the carriage of excess adipose tissue are also evident in the obese (Lawrence & Kopleman, 2004). These include osteoarthritis of weight bearing joints (British Nutrition Foundation, 1999), aches and pains, and dyspnea on mild exertion (Lawrence & Kopleman, 2004). Respiratory diseases such as obesity hypoventilation syndrome and obstructive sleep apnea syndrome are also strongly associated with obesity (Formiguera & Canton, 2004). Inability to take part in activities of daily living, immobility, psychosocial and economic problems, and disability are often associated problems seen in obese individuals, in addition to the major co-morbidities (Deitel & Shikora, 2002).

The weight gain associated with adverse outcomes and increased morbidity, increases in a linear fashion with increases in BMI (Aronne & Segal, 2002; Allan, 2004). For example obese women are almost 13 times more likely to develop T2DM than non-obese women, whilst obese men are twice as likely to have hypertension compared to non-obese men (Pi-Sunyer, 2004). The risk (in comparison with a BMI below 23kg.m^{-2}) increases more than 20-fold when BMI exceeds 35kg.m^{-2} (Bray, 2003). Stroke is twice as common among the morbidly obese and obese women have twice the risk of developing bowel or rectal cancer, and osteoarthritis than their normal weight counterparts (Abraham & Llewellyn-Jones, 2001). The health consequences

of obesity are vast, with virtually all people with BMI > 40 kg.m² developing some physical symptoms by the age of 40, and the majority requiring medical attention or drug therapy for secondary conditions by the age of 50 years or 60 years (Bray, 2003). However, although the relationship of obesity to mortality indicates that obesity begins to be of clinical importance at a BMI of approximately 30 kg.m² examination of morbidity data shows that health penalties start at a much lower level (British Nutrition Foundation, 1999). For example, in Europe and North America, between 8% and 15% of disability adjusted life years lost are attributed to overweight and obesity (WHO, 2003). This further highlights the importance of treating obesity.

Although the risk of obesity related co-morbidity increases as BMI increases, increased risk also relates to body fat distribution (Eckel, 1997). For example, Janssen et al., (2002) found that individuals with high WC values were increasingly likely to have hypertension, diabetes, and dyslipidemia, compared with those with normal WC values. There is however reluctance towards replacing BMI with WC as a clinical health risk measurement (Bray, 2004), with a general consensus that WC cannot fully replace BMI (Bigaard et al., 2003) although it's use as a measure of central adiposity may improve the criteria for assessing risk (Janssen et al., 2004). When examining the independent associations of WC and BMI with all-cause mortality in a cohort of middle-aged men and women, Bigaard et al (2003) found that WC alone is a good predictor of mortality when BMI is >25, however when BMI is <25 BMI is also important for the mortality rate. Bigaard et al., (2004) suggest that further studies investigating other endpoints related to obesity are needed.

2.4.2.2 Obesity and metabolic syndrome

The increasing prevalence of obesity has been accompanied by a parallel increase in the prevalence of the metabolic syndrome (MetSyn) (Liberopoulos et al., 2005). MetSyn is a clustering of inter-related risk factors that identify individuals at increased risk of developing CVD and T2DM (Byrne & Wild, 2007). The concept of MetSyn has evolved over recent years,

but with the recognition that obesity is becoming a major global health problem, the interest in this syndrome has experienced a dramatic increase as well as a conceptual evolution (Laclaustra et al., 2007).

Four organisations have provided clinical criteria for diagnosing MetSyn including WHO, the European Group for Study of Insulin Resistance (EGIR), the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) and the International Diabetes Federation (IDF) (Table 2.8). In 1998 the WHO clinical criteria required the presence of insulin resistance (Alberti & Zimmet, 1998). The EGIR criteria also consider the presence of insulin resistance for the clinical diagnosis of the MetSyn, although unlike the WHO criteria does not require results of a glucose tolerance test (Wild & Bynre, 2006). The NCEP ATP-III criteria eliminated the insulin resistance requirement in 2001 but require the presence of 3 out of 5 equally weighted abnormalities. Furthermore, the IDF clinical criteria require the presence of abdominal obesity (i.e. increased WC) (Alberti, Zimmet & Shaw, 2005) and emphasised ethnic-specific cut-offs for this measure (Alhassan et al., 2008). NCEP ATP III considers abdominal obesity one of the 5 equally weighted metabolic abnormalities (NCEP Expert Panel, 2001). It is important to note that the existing clinical criteria for MetSyn can lead to substantially different estimated prevalence of MetSyn within a population (Alhassan, et al., 2008) and therefore could potentially impact research findings. Much research has examined similarities and differences between the MetSyn clinical criteria and the impact these criteria have on identifying individuals with the condition. For example, in a study of 256 postmenopausal women (mean BMI $32 \pm 4 \text{ kg.m}^{-2}$), up to 23% of participants were classified differently as either having or not having MetSyn, according to the clinical criteria used (Alhassan et al., 2008). These results confirm results of previous study conducted by de Simone et al., (2007), who reported that IDF clinical criteria identified more individuals as having MetSyn than other clinical criteria. A higher rate of diagnosis has also been seen in WHO criteria compared with ATP III (25.1 vs. 23.9%) in a population of 8608 participants in the USA (Lin, Chiou et al., 2004).

Table 2.8. Features of the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP-III), International Diabetes Federation (IDF), World Health Organisation (WHO), and the European Group for the Study of Insulin Resistance (EGIR) definitions of MetSyn

Risk Factor	NCEP ATP III	IDF	WHO	EGIR
	At least 3 of 5 factors (TG and HDL counted separately)	Central obesity plus at least 2 other factors	Impaired glucose tolerance or diabetes and/or insulin resistance plus 2 other factors	Presence of fasting hyperinsulinaemia (highest 25%) plus 2 other factors
Central obesity	Waist Circumference ≥102 cm (men) ≥88cm (women)	Waist Circumference ≥94cm (men), ≥80cm (women)	WHR ≥0.9 (men), ≥0.85cm (women) or BMI >30kg.m ⁻²	Waist Circumference ≥94cm (men), ≥80cm (women)
Elevated serum triglycerides	≥1.7 mmol.L ⁻¹	≥1.7 mmol.L ⁻¹	≥1.7 mmol.L ⁻¹	≥2.0mmol.L ⁻¹ or treatment
Reduced HDL cholesterol	<1.0mmol.L ⁻¹ (men), <1.3mmol.L ⁻¹ (women)	<1.0mmol.L ⁻¹ (men), <1.3mmol.L ⁻¹ (women)	<0.9mmol.L ⁻¹ (men) <1.0mmol.L ⁻¹ (women)	<1.0mmol.L ⁻¹ or treatment
Glucose intolerance	≥110mg/dl	≥100mg/dl	≥110mg/dl	≥110mg/dl but non-diabetic
Elevated blood pressure	≥130mmHg systolic ≥85mmHg diastolic	≥130mmHg systolic ≥85mmHg diastolic	≥140mmHg systolic ≥90mmHg diastolic	≥140mmHg systolic ≥90mmHg diastolic
Microalbuminuria	-	-	≥20 µg min ⁻¹ or albumin:creatinine ratio > 30mg.g ⁻¹	-

BMI, body mass index; HDL, high-density lipo-protein; TG, triglycerides
(Adapted from Byrne & Wild, 2006)

The prevalence of MetSyn varies with the country, ethnic origin and the definition used (Bauducea et al., 2007). It is estimated that 47 million US adults meet the NCEP criteria for MetSyn (Liberopoulos et al., 2005) and in the UK the prevalence of MetSyn in adults is estimated to be at least 15% (Byrne & Wild, 2007). MetSyn is clinically important and relevant to primary care due to the increased risk associated with it (Fig.2.6). For example MetSyn accounts for around half of attributed diabetes, a quarter of incident cardiovascular (CV) disease, and CV mortality associated with MetSyn is estimated at 37% (Byrne & Wild, 2007) to 291% (Lakka et al., 2002).

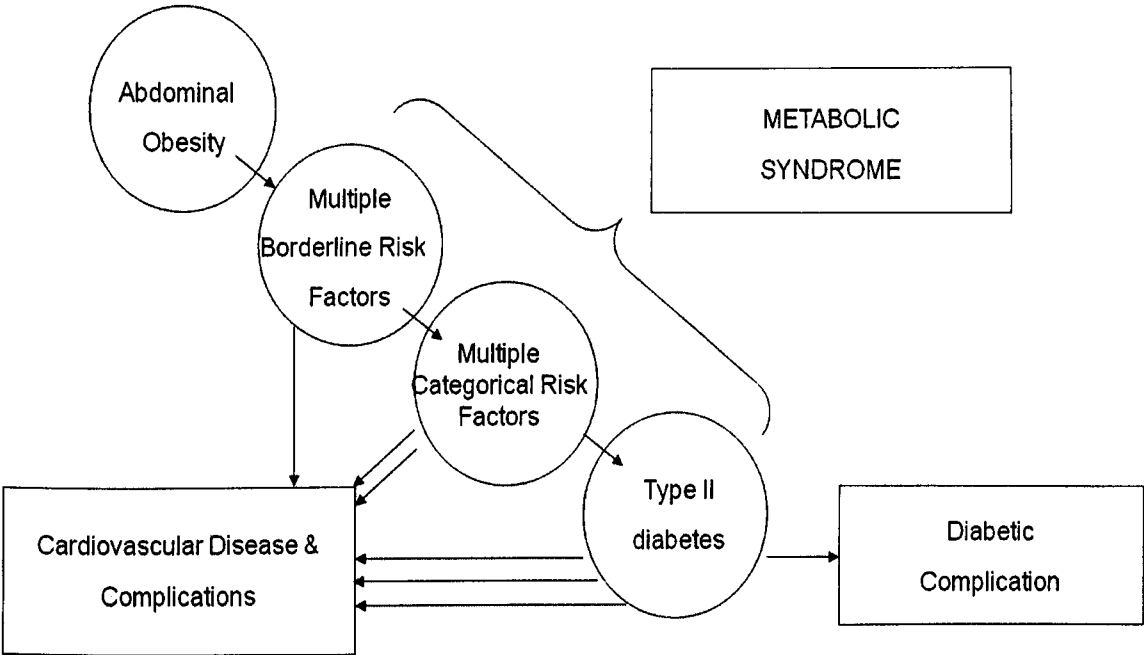


Figure 2.6. Progression and outcome of the MetSyn (Grundy, 2006).

The development of specific recommendations for managing MetSyn has been limited due to lack of published randomised controlled trials, however it is estimated that 50% of the diseases in MetSyn can be treated by lifestyle modification. These lifestyle modifications include weight loss (in overweight/obese individuals), increased physical activity and dietary modification (Byrne & Wild, 2006). Due to the absence of an identified unifying pathophysiological mechanism of MetSyn (Cornier et al., 2008), these treatment modalities aim to improve the individual MetSyn parameters, as opposed to treating MetSyn in itself.

Weight loss is a well established method for treating all components of MetSyn (NIH, 2008) and is best achieved by reducing energy intake and increasing energy expenditure (Eckel et al., 2005). The primary goal is to achieve a 10% reduction in total body weight in overweight/obese individuals with MetSyn (Grundy, 2007). Dietary composition for the treatment of MetSyn is consistent with general dietary guidelines that recommend increased intake of fruit and vegetables, low intake of saturated and trans fats and reduced consumption of sugars. However, long term data suggest that key predictors of metabolic risk factor reduction are dependent upon degree of dietary adherence and associated weight loss, rather than diet type (Dansinger & Schaefer, 2007). Regular and sustained physical activity has also been shown to prevent MetSyn (Ford et al., 2005) and research evidence suggests that physical activity improves all components of MetSyn such as lowering LDL-C and TG levels (Katzel, 1997), increasing HDL-C levels (Liberopoulos et al., 2007; Reaven, 2008) and reducing hypertension (Whelton et al., 2002). However, the amount and intensity of physical activity required to prevent or reverse MetSyn has yet to be established.

While lifestyle modification resulting in weight loss can achieve clinically significant benefits, approximately 50% of people with MetSyn do not reach treatment targets without drugs (Byrne & Wild, 2006). Guidelines for the treatment of obesity recommend consideration of pharmaceutical therapy for weight loss for individuals with a BMI $\geq 30\text{kg.m}^{-2}$, or those with a BMI $\geq 27\text{kg.m}^{-2}$ and associated comorbidities. Therefore, the majority of patients who meet MetSyn criteria will meet the criteria for considering pharmaceutical weight loss therapy. Sibutramine and orlistat are currently the only approved weight loss drugs and have been shown to have therapeutic effects on individual components of MetSyn (Bray & Greenway, 2007). However, there are no specific drug treatments recommended for MetSyn beyond medications that improve its individual components, namely hypertension and dyslipidemia (Meigs et al., 2003).

MetSyn risk factors tend to co-exist more commonly than would be expected by chance. For example, diabetes and obesity are twice as common among people with hypertension compared to those with normal blood pressure (Hardman & Stensel, 2009). A defining feature of the MetSyn is insulin resistance and it has been argued that the clustering of components that make up MetSyn only occurs in insulin-resistant persons (Harman & Stensel, 2009). Elevated insulin levels can lead, directly or indirectly, to the characteristic metabolic abnormalities seen in individuals with MetSyn. For example, several potential mechanisms have been proposed to explain the association between insulin resistance and hypertension, including increases of the sympathetic nervous system caused by insulin resistance and overactivation of the renin-angiotensin-aldosterone system caused by hyperinsulinaemia (Engeli & Sharma, 2001). Insulin also exerts multiple influences on lipid metabolism, promoting the synthesis of fatty acids in the liver and inhibiting the breakdown of fat in adipose tissue, leading to high plasma concentrations of triglycerides (Harman & Stensel, 2009).

The IDF consider abdominal obesity an essential criterion, and assign this abnormality a central aetiological role. Nearly half the variation in insulin sensitivity amongst individuals is accounted for by variations in body fat distribution, and there is increasing evidence that abdominal fat accumulation is related to hypertension, hypertriglyceridemia and lipo-protein disturbances (Bonithon-Kopp et al., 1992). Weight reduction can improve insulin sensitivity and glucose tolerance, thus over-fatness and insulin resistance are closely linked. Furthermore, numerous studies have identified the link between abdominal obesity and insulin resistance (Ascaso et al., 2003, Haffner, 2006). However, whether insulin resistance is causative of abdominal obesity, or both correlate with some other factor is unknown and there is no clear proof of a causal link between visceral fat accumulation and insulin resistance.

Whether physique, constitution and disease are interlinked to each other has always been a great point of interest (Singh, 2007). Numerous large scale epidemiological cohort studies have established that excess body weight (as established by BMI) is an important risk factor for a range of primary co-morbid conditions (Steinbeck, 2004; Wolk et al., 2003; Gus et al., 2004). Furthermore, as discussed above, abdominal obesity is also linked to range of metabolic disturbances. There is also some limited documented evidence of characteristic somatotypes being associated with some diseases and conditions (Herrera et al., 2004). For example, a combination of high scores on the sub-component of mesomorphy and endomorphy are believed to increase cardiovascular risk (Carter & Heath, 2005) and adverse lipid profiles have also been identified in individuals with dominant endomorphy and mesomorphy sub-component scores (Carter & Heath, 2005). Furthermore, a cross-sectional survey conducted by Koleva et al., (2002) examined the association between global somatotype and its sub-components and the prevalence of several chronic diseases.

2.4.3 Psychological consequences of obesity

Being obese can carry a strong, negative social stigma (Puhl & Brownell, 2001) and discriminatory attitudes and behaviours occur towards the overweight and obese in many areas including employment (Pingitore et al., 1994; Roehling, 1999), healthcare (Oberriede et al., 1995; Wadden et al., 2000) and education (Neumark-Sztainer et al., 1999). For example, in the United States late adolescent obesity in women in 1981 was found to correlate with lower incomes in 1988, compared to women who had not been overweight (Gortmaker et al., 1993). In the UK, men who had been obese at 16 years in 1974 earned 7.4% less than their non-obese peers at age 23 (Sargent & Blanchflower, 1993). Furthermore, Viner and Cole (2005) found that men who were obese in adulthood were more likely to have left school without any qualifications, with similar findings reported by Gortmaker et al. (1993) and Laitinen et al. (1999) in female cohorts. For some obese individuals negative stigmatisations, discriminatory attitudes and behaviours,

particularly evident in modern Western countries (Abraham & Llwellyn-Jones, 2001), can trigger or exacerbate psychological issues such as decreased mood, increased anxiety, low self-esteem and body image disturbances (Lawrence & Kopleman, 2004; Swinburn & Egger, 2004). Women and adolescent girls appear to suffer these negative consequences the most; this is potentially due to increases societal pressures on women to be thin (Carpenter et al., 2000).

There is an extensive body of research literature that recognises the detrimental physiological consequences of obesity (Steinbeck, 2004) however the psychological distress assumed in obese people is not supported by consistent literature (Carr et al., 2007; Hill, 2005). Studies such as those by Dong et al. (2004), Wadden et al., (2006) and Carr et al., (2007) have found a negative relationship between body weight and psychological well-being and Schwartz and Brownell (2004) found obesity to be a cause of psychological distress leading to reduced quality of life. Furthermore, in a structured 12-week weight loss program Rippe et al. (1998) found weight loss to yield significant health and psychological benefits in moderately obese females and recommendations were made to consider psychological aspects of obesity and weight loss as well as physiological features. In contrast, other studies have found no significant association between obesity and negative psychological consequences. For example in a sample of 322 patients with T2DM, Herpertz et al., (2000) identified no relationship between BMI and depressive symptomatology, low self-esteem or general psychiatric symptomatology. Some studies have also demonstrated an apparent protective effect of excess body weight on psychological distress (Fabricatore & Wadden, 2004; Goldney et al., 2009).

Methodological shortcomings have been identified in the area of obesity and psychological variables, in particular regarding body image. Literature that has focused on psychological correlates of obesity within obese populations has tended to focus on severe obesity (Adami et al., 1999; Batsis et al., 2009; Bocchieri et al., 2002; Thonney et al., 2010). There is considerable

heterogeneity in the obese population (Carr et al., 2007; Kimm et al., 1997; Schwartz & Brownell, 2004) therefore it is not clear how these findings generalise to the larger population of overweight, obese individuals. It has been hypothesised that extremely obese persons appear to be at greater risk of psychological distress compared to moderately obese individuals (Fabricatore & Wadden, 2004) with Hill and Williams (1998) finding body dissatisfaction to worsen with increasing degree of obesity. Obesity has also been associated with increased levels of depression, mainly among persons with severe obesity (Onyike et al. 2003). Friedman and Brownell (1995) conducted a review on the psychological correlates of obesity and identified the need to move on from research that compared obese and non-obese individuals and consider the influence of degree of obesity.

Substantial evidence suggests a link between physical activity and reduced anxiety (Steptoe & Butler, 1996; Thirlaway & Benton, 1996), decreased depression (Blumenthal et al., 1999) and improved cognitive functioning (Sallis et al., 1999). However research has shown that the physiological adaptation achieved through being physically active has no direct influence on psychological functioning (Plante et al., 1998). It has since been hypothesised that the psychological benefits of physical activity programmes are related more to the perception of improved fitness than to objective improvements (Delignieres et al., 1994). Fox (2000) also suggests that actual physical changes may be unnecessary to improve self-perceptions. Although correlational analysis cannot establish causation, more recent research findings of studies conducted by Shaw et al., (2000), Van Vorst et al. (2002), and Polman and Borkoles (2007), oppose the view that changes in self-perceptions are purely based on psychological mechanisms. However, further research is needed to identify whether the changes in self-perceptions are explained by physiological and/or anthropometrical variables (Polman & Borkoles, 2007).

It is also worth noting that there is no clear separation between psychological factors that function as causes of obesity and the psychological effects of

obesity (Fabricatore & Wadden, 2004), although the conclusion that psychological factors associated with obesity are more likely to be consequences than causes is generally accepted (Lissner, 1997).

3. GENERAL METHODS AND INSTRUMENTATION

This chapter details the general data collection methods and techniques utilized in the studies that comprise this thesis. Specific methodological details will be provided in subsequent chapters. Particular mention is made of quality assurance methods implemented to increase reliability and validity of data. Additionally, approaches to somatotype analysis are detailed. All studies received ethical approval from the BioSciences Research Ethics Committee of the University of Portsmouth.

3.1 Anthropometrical data collection

To ensure standardisation of data collection procedures, all restricted anthropometric profiles (Table 3.1) were conducted in accordance with ISAK guidelines (Marfell-Jones et al., 2006), by the author, a level II accredited anthropometrist.

Table 3.1. Measurements included in a restricted anthropometric profile

Basic	Skinfolds (mm)	Girths (cm)	Breadths (cm)
Height (cm)	Triceps	Arm (relaxed)	Humerus
Weight (kg)	Subscapular	Arm (flexed & tensed)	Femur
	Biceps	Waist (minimum)	
	Iliac crest	Gluteal (maximum)	
	Supraspinale	Calf	
	Abdominal		
	Front thigh		
	Medial calf		

Images A and B (Fig.3.1) are examples of landmarks that are used to identify the exact location of the measurement sites. These are identifiable skeletal points which generally lie close to the body's surface. Locating and marking the landmark is pre-requisite for reproducible and valid measurements (Stewart et al., 2004). Images C and D (Fig. 1) represent examples of skinfold measures.

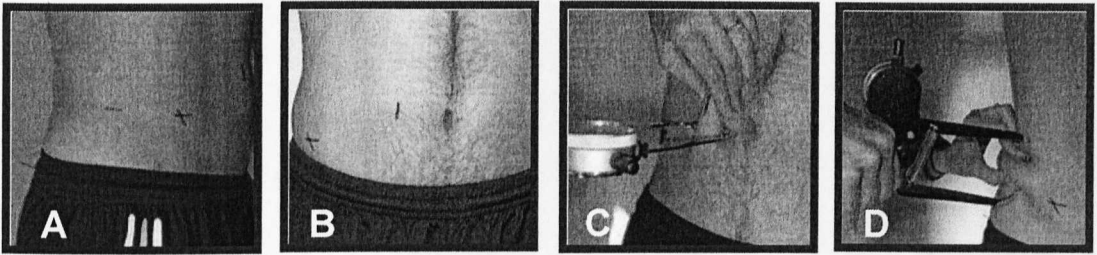


Figure 3.1. Landmarks for iliac crest (A) and supraspinale skinfolds sites (B) and examples of abdominal skinfold (C) and iliac crest skinfold (D) measurements (Ross et al., 1999)

The skinfold was grasped and lifted (raised) at the marked line (Fig.3.2a) so that a double fold of skin plus the underlying subcutaneous adipose tissue is held between the thumb and index finger of the left hand (Fig.3.2b). The caliper, held at a 90° to the surface of the skinfold at all times, was applied 1cm away from the edge of the thumb and finger at a depth of approximately mid-fingernail (Fig.3.2c). Measurement was recorded two seconds after the full pressure of the caliper was applied.

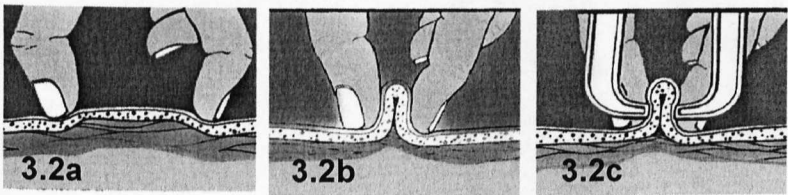


Figure 3.2. Examples of skinfold measuring technique (healthgoods.com, 1998).

A cross hand-technique was used for all girth measurements, ensuring no visible indentation of the skin, as depicted in images E and F (Fig.3.3). Considerable pressure was applied when conducting breadth measurements in order to compress the soft tissue overlying the bone in obese individuals (G & H – Fig.3.3).

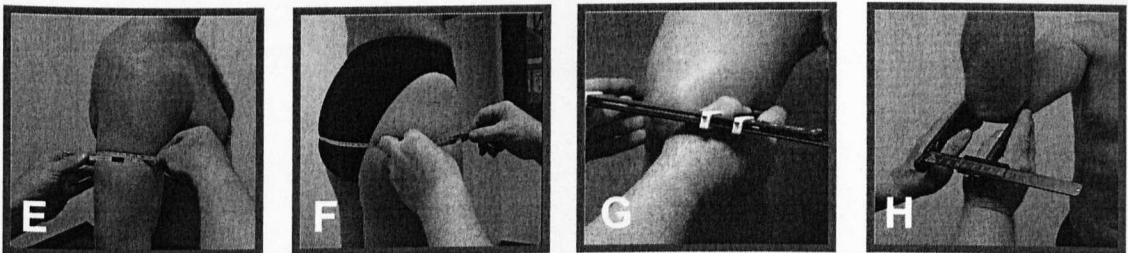


Figure 3.3. Examples of arm relaxed and gluteal girths (E&F, respectively) and humerus breadth (G) and femur breadth (H) measurements (Ross et al., 1999)

3.1.1 Equipment

Body height and mass were measured using a portable stadiometer (Leicester, Bodycare, UK) and electronic weighing scales (524J/BMI, Avery-Weightonix, UK), to a precision of 0.1cm and 0.1kg respectively. Participants wore minimal clothing when being weighed. Common problems associated with the accuracy of anthropometric measures include use of calipers that do not exert constant pressure at the skinfold site, and use of a stretchable, cloth tape measure (Utley, 1990; Van Loan, 1997). Therefore, in the present studies skinfolds were measured using calibrated Harpenden skinfold calipers (John Bull, UK) and girths using Thinline anthropometric tape (Lufkin W606PM, USA). Breadths were measured using small sliding calipers (Rosscraft, UK). Replicate determinations of each measure were made to calculate a mean score. If any two independent assessments varied by more than 5% (skinfolds) and 1% (girths and breadths), a third measurement was taken and the median score recorded.

3.1.2 Data handling

Using the data collected in the anthropometric profile, BMI (kg.m^{-2}) and WHR (waist girth/gluteal girth) were calculated. $\Sigma 8\text{SF}$ was calculated by summing the skinfolds listed in Table 3.1. The calculations of the anthropometric somatotype sub-components, which use 10 variables, are shown in Box 3.1. Transformation of skinfold measures to body density (BD) was done using Durnin and Womersley's (1974) equation, then further transformation to %BF using the Siri equation (Box 3.2).

A number of prediction equations are available in the literature (Norton & Olds, 1996) however it is important that participants are measured using an equation derived from a similar population; as using an inappropriate equation may produce systematic prediction error in estimating body composition (Brooks et al., 1996). In contrast to other equations derived from athletic populations, Durnin and Womersley's (1974) sex specific

equations used a sample of 209 males and 272 females with varying body types (from obesity clinics, health clubs, sport organisations and other sources). Therefore its use in an overweight/obese population was deemed more appropriate.

To calculate endomorphy:

$$\text{Endomorphy} = -0.7182 + 0.1451 \times \sum \text{SF} - 0.00068 \times \sum \text{SF}^2 + 0.0000014 \times \sum \text{SF}$$

To calculate mesomorphy:

$$\text{Mesomorphy} = 0.858 \times \text{HB} + 0.601 \times \text{FB} + 0.188 \times \text{CAG} + 0.161 \times \text{CCG girth} - \text{H} \times 0.131 + 4.5$$

To calculate ectomorphy:

Three equations are used according to the height-weight ratio (HWR):

If HWR is greater than or equal to 40.74 then

$$\text{Ectomorphy} = 0.732 \times \text{HWR} - 28.58$$

If HWR is less than 40.75 and greater than 38.25 then

$$\text{Ectomorphy} = 0.463 \times \text{HWR} - 17.63$$

If HWR is equal to or less than 38.25 then

$$\text{Ectomorphy} = 0.1$$

Where: $\sum \text{SF}$ = (sum of triceps, subscapular and supraspinale skinfolds) \times (170.18 height in cm); HB = humerus breadth; FB = femur breadth; CAG = corrected arm girth; CCG = corrected calf girth; H = height; HWR = height/cube root of weight.

CAG and CCG are corrected for the triceps or calf skinfolds respectively as follows: CAG = flexed arm girth - triceps skinfold/10; CCG = maximal calf girth - calf skinfold/10.

Box 3.1. Equations to derive somatotype sub-component scores (Carter, 2002).

Durnin and Womersley's body density prediction equation (1974)

Males:

$$BD = 1.1765 - 0.0744 (\log_{10}X_1)$$

Where; BD= body density; $X_1(\text{mm}) = \sum 4$ skinfolds (triceps, biceps, subscapular, iliac crest in mm)

Females:

$$BD = 1.1567 - 0.0717 (\log_{10}X_1)$$

Where: BD = body density; $X_1(\text{mm}) = \sum 4$ skinfolds (triceps, biceps, subscapular, supraspinale in mm)

Siri %BF prediction equation (1961)

$$\%BF = (495 / \text{Body Density}) - 450$$

Where: %BF = percent body fat; BD = body density

Box 3.2. Equations to derive body density (Durnin & Womersley, 1974) and %BF (Siri, 1961).

3.1.3 Technical error of measurement

As with any quantitative biological measure, in anthropometric assessment it is important to minimize error (Moreno et al., 2003). High levels of error can render statistical comparisons invalid, and errors can artificially inflate the variance associated with a particular measurement (Bailey & Byrnes, 1990). Furthermore, empirical data have shown that the measurement error can compromise a wide variety of univariate and multivariate statistical methods, particularly those that rely on correlation, regression, and covariance (Halligan, 2002). Therefore prerequisites for increased precision and improved interpretation of results include good quality control, involving both reduction in instrumentation and human error (Goto & Mascie-Taylor, 2007).

A number of methods of measuring inconsistency are available but the preferred method involves calculation of either intra- or inter-technical error

of measurement (TEM) initially, relative TEM (%), and then the coefficient of reliability (Ulijaszek & Kerr, 1999). TEM gives information on the error margin of a trait and therefore is an accuracy index (Goto & Mascie-Taylor, 2007). This index is adopted by ISAK (Perini et al., 2005). If the same assistant has measured an individual on two occasions (a measure of intra-TEM), or two assistants have measured the same individual (inter-TEM), then the formula for TEM is:

$$\sqrt{\frac{\sum D^2}{2N}}$$

where D is the difference between the two measurements, and N is the sample size.

The units of TEM are the same as the units of the measurements to which they apply. Hence, for skin-folds the units are in millimetres and circumferences are in centimetres etc. It is also possible to compute the relative TEM (%TEM), which provides an estimation of the error magnitude relative to the size of the measurement (expressed as a percentage) and is analogous to the coefficient of variation. This is calculated by dividing the TEM by the mean measurement:

$$\%TEM = \left(\frac{TEM}{\bar{X}} \right) * 100$$

Measurement of at least 10 participants must be obtained for the calculation of intra- and inter-observer errors of measurement (Moreno et al., 2003). To examine reliability and ensure minimal error within the current studies, the anthropometrists' intra-technical error or measurement (intra-TEM), relative TEMs and co-efficient of reliability were calculated. All were within acceptable ranges as defined by ISAK (Appendix 4). Table 3.2 gives the mean, standard deviation (SD) and intra-TEM of anthropometrical measurements collected in 3 population groups; overweight (n=20), obese (n=20), and morbidly obese (n=16).

Table 3.2. Mean (\pm SD) and intra-TEM of anthropometrical measures in 3 population groups; overweight ($n=20$), obese ($n=20$), and morbidly obese ($n=16$)*.

Anthropometric Measure	Overweight		Obese		Morbidly Obese	
	Mean \pm SD	Intra TEM	Mean \pm SD	Intra TEM	Mean \pm SD	Intra TEM
Height (cm)	165.3 \pm 6.4	0.04	164.3 \pm 7.6	0.06	163.68 (17.1	0.02
Mass (kg)	75.10 \pm 6.6	0.00	93.4 \pm 12.9	0.00	130.8 \pm 19.6	0.00
Triceps (mm)	19.5 \pm 7.1	0.47	24.9 \pm 5.7	0.56	30.0 \pm 6.0	0.65
Subscapular (mm)	18.9 \pm 5.6	0.42	28.1 \pm 6.6	0.57	35.5 \pm 7.8	0.89
Biceps (mm)	11.3 \pm 4.2	0.27	16.8 \pm 6.4	0.47	22.8 \pm 5.2	0.58
Iliac Crest (mm)	20.5 \pm 5.4	0.42	25.6 \pm 4.5	0.60	34.6 \pm 6.9	0.76
Supraspinale (mm)	15.1 \pm 5.3	0.42	22.8 \pm 5.4	0.50	25.6 \pm 5.2	0.60
Abdominal (mm)	24.6 \pm 7.3	0.60	30.5 \pm 8.1	0.80	35.0 \pm 7.8	0.91
Front Thigh (mm)	29.1 \pm 11.9	0.55	37.5 \pm 12.2	0.73	54.9 \pm 16.6	0.90
Medial Calf (cm)	16.6 \pm 7.0	0.30	24.2 \pm 8.3	0.41	35.8 \pm 9.9	0.44
Arm relaxed (cm)	31.35 \pm 2.21	0.15	36.6 \pm 2.5	0.19	43.9 \pm 4.1	0.15
Arm flexed (cm)	31.6 \pm 2.0	0.14	37.5 \pm 3.1	0.22	44.7 \pm 4.6	0.21
Waist minimum (cm)	93.5 \pm 10.2	0.27	114.1 \pm 11.6	0.27	138.8 \pm 10.7	0.51
Hips gluteal (cm)	104.8 \pm 4.7	0.22	117.1 \pm 6.5	0.32	138.0 \pm 11.5	0.43
Calf maximum (mm)	38.1 \pm 3.0	0.08	42.0 \pm 4.5	0.08	48.4 \pm 3.4	0.14
Humerus (cm)	6.6 \pm 0.4	0.03	6.8 \pm 0.5	0.04	7.2 \pm 0.6	0.04
Femur (cm)	9.6 \pm 0.5	0.03	10.3 \pm 0.4	0.05	11.3 \pm 0.5	0.05

*as defined in Table 2.1

Figure 3.4 shows the relative TEM expressed as a percentage. ISAK defines the acceptable limits of tolerance as 5% for skin-folds and 1% for all other measures. In each population group all measurements were under these thresholds (Fig.3.4). However, it is noted that the % variation increased concurrently with degree of obesity, with the greatest intra-observer % TEM scores seen in the morbidly obese group. Figure 3.4 also illustrates that within the morbidly obese population, skinfolds around the trunk had the highest intra-observer %TEM, which reflects the difficulty in taking up a fold of skin correctly in that area of the body.

From TEM, the coefficient of reliability (R) can be determined, which ranges from 0 (not reliable) to 1 (complete reliability). This coefficient shows the proportion of the between-subject variance (total measurement variance) that is not due to measurement error (WHO, 2006). The formula to determine the coefficient of reliability is:

$$1 - \left(\frac{(TEM)^2}{(SD)^2} \right) \quad \text{where SD is the standard deviation of all measurements}$$

An R of 0.8 means that 80% of the total variability is true variation, while the remaining proportion (20%), is attributable to measurement error. This is described by the WHO Multicentre Growth Reference Study (2006) as imprecision and unreliability. Although there are no recommended values for R, Ulijaszek & Kerr (1999), suggest that coefficients of reliabilities above 0.95 (i.e. a human measurement error of up to 5%) are indicative of good quality control. However, even at R values of approximately 95%, there is the occasional gross measurement error that is likely to have important consequences. Only when R is in the region of 99% is such an error unlikely (Moreno et al., 2003). R was calculated for the three aforementioned population groups and reliability for all measures ranged from 98% to 100%, thus indicating high levels of reliability and minimal error.

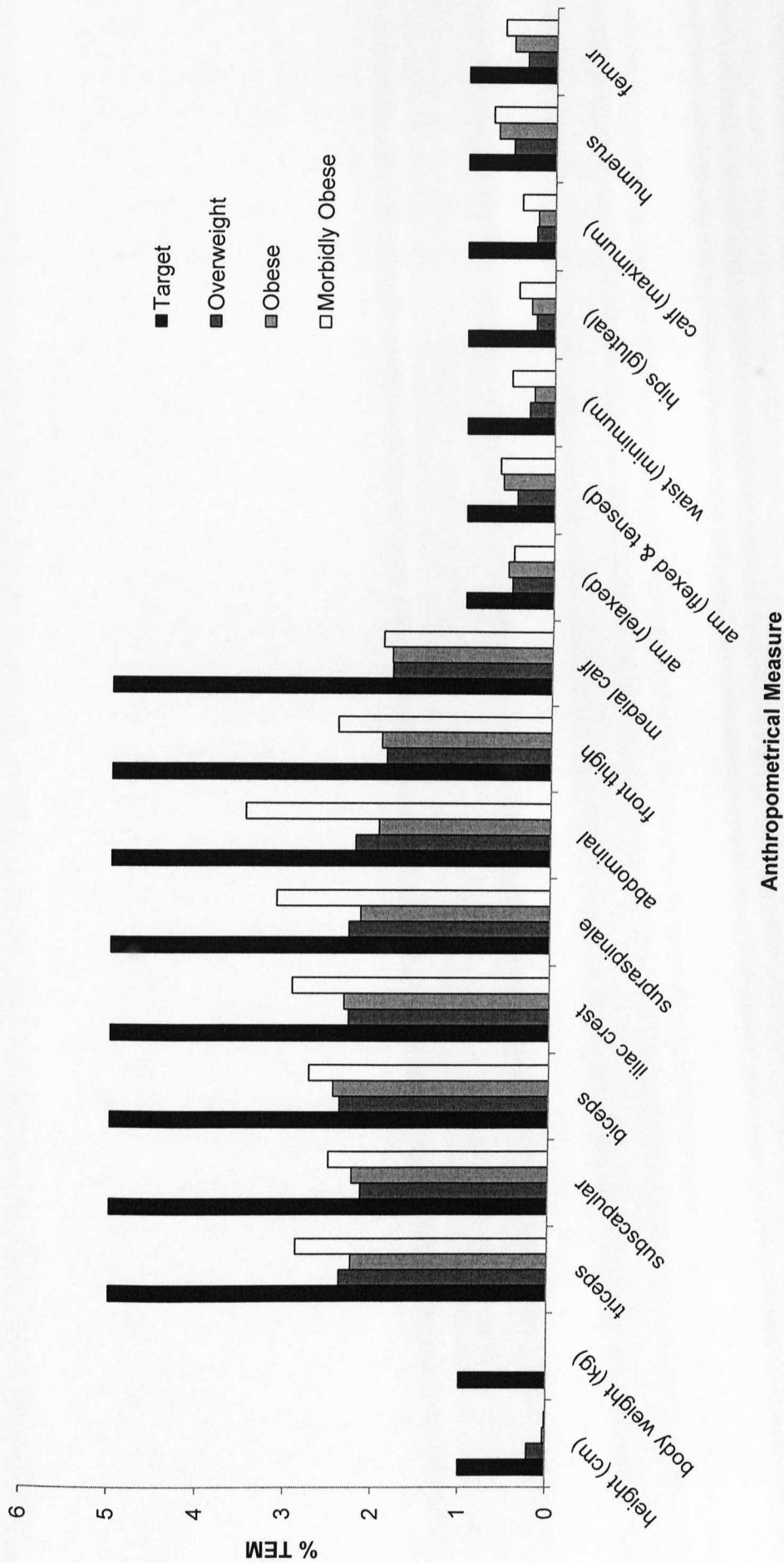


Figure 3.4. Intra-observer TEM (%) of anthropometrical measures in 3 population groups; overweight (n=20), obese (n=20), and morbidly obese (n=16).

The use of multiple measurers to collect data risks the introduction of systematic measurement errors with the potential to affect the results (Adams et al., 2002). In particular, research evidence suggests that waist and hip circumference show strong between-observer differences and should, where possible, be carried out by one observer (Ulijaszek & Kerr, 1999). All data collection in the forthcoming studies were conducted by one observer thus eliminating between-observer error. However, to further examine the anthropometrist's expertise, inter-observer TEMs (compared with a level 3 criterion anthropometrist with over 10 years practical experience) were also calculated. Tolerance levels were again within acceptable limits as governed by ISAK (Appendix 4).

These quality assurance methods, including standardised data collection methodology and rigorous training and maintenance, similar to those utilised by the World Health Organisation in the Multicentre Growth Reference Study (2006), have been implemented to further increase reliability of data. Frequent equipment calibration was also conducted to minimise instrument error (Goto & Mascie-Taylor, 2007).

3.2 Approaches to somatotype analysis

Specific statistical procedures to analyse anthropometric data are detailed in subsequent chapters. However, somatotype is a 3-number rating; therefore for meaningful analysis unique analytical procedures are required. Prior to the development of sophisticated analyses for analysis of the somatotype as a whole, the somatotype component ratings were analysed separately. As discussed by Marfell-Jones et al. (2006), this prematurely separates the somatotype into three components and does not analyse the whole somatotype. The strength of the somatotype concept is the combination of all three component values into one expression (Ducquet & Carter, 2009). Specialised techniques to analyse the somatotype as a whole include somatotype categories and somatotype attitudinal distance (SAD) techniques (Ducquet & Carter, 2009).

Somatotypes with similar relationships between the dominance of components are grouped into categories named to reflect those relationships (Norton & Olds, 1996). This gives a more qualitative description of the individual somatotype, in terms of the dominant component or components (Duquet & Carter, 2001). A total of 13 somatotype categories were defined by Carter and Heath (1990) (Table 3.3).

Table 3.3. Somatotype categories and corresponding dominance variation, as defined by Carter and Heath (1990).

Somatotype Category	Dominance Variation
Central	No component differs by more than one unit from the other two.
Balanced endomorph	Endomorphy is dominant and mesomorphy and ectomorphy are equal (or do not differ by more than one-half unit).
Mesomorphic endomorph	Endomorphy is dominant and mesomorphy is greater than ectomorphy.
Mesomorph endomorph	Endomorphy and mesomorphy are equal (or do not differ by more than one half unit), and ectomorphy is smaller.
Endomorphic mesomorph	Mesomorphy is dominant and endomorphy is greater than ectomorphy.
Balanced mesomorph	Mesomorphy is dominant and endomorphy and ectomorphy are equal (or do not differ by more than one-half unit).
Ectomorphic mesomorph	Mesomorphy is dominant and ectomorphy is greater than endomorphy
Mesomorph ectomorph	Mesomorphy and ectomorphy are equal (or do not differ by more than one-half unit), and endomorphy is smaller.
Mesomorphic ectomorph	Ectomorphy is dominant and mesomorphy is greater than endomorphy.
Balanced ectomorph	Ectomorphy is dominant and endomorphy and mesomorphy are equal (or do not differ by more than one-half unit).
Endomorphic ectomorph	Ectomorphy is dominant and endomorphy is greater than mesomorphy.
Balanced ectomorph:	Ectomorphy is dominant and endomorphy and mesomorphy are equal (or do not differ by more than one-half unit).
Endomorph-ectomorph:	Endomorphy and ectomorphy are equal (or do not differ by more than one-half unit), and mesomorphy is lower.
Ectomorphic endomorph:	Endomorphy is dominant and ectomorphy is greater than mesomorphy.

The differences or similarities in somatotypes of subjects or groups of subjects can be visualised by plotting them on a somatochart, shown in Figure 3.5 (Duquet & Carter, 2001). This provides a bi-dimensional representation of the tri-dimensional somatotype (Norton & Olds, 1996). The left apex represents a 7-1-1 (extreme endomorph) somatotype; the top apex represents a 1-7-1 (extreme mesomorph) somatotype; and the right apex represents a 1-1-7 (extreme ectomorph) somatotype. The centre of the somatochart represents a (balanced) somatotype (Siders & Rue, 1992). Somatotypes lying outside the arc-sided triangle can be identified as extremes for their particular category (Carter & Heath, 2005).

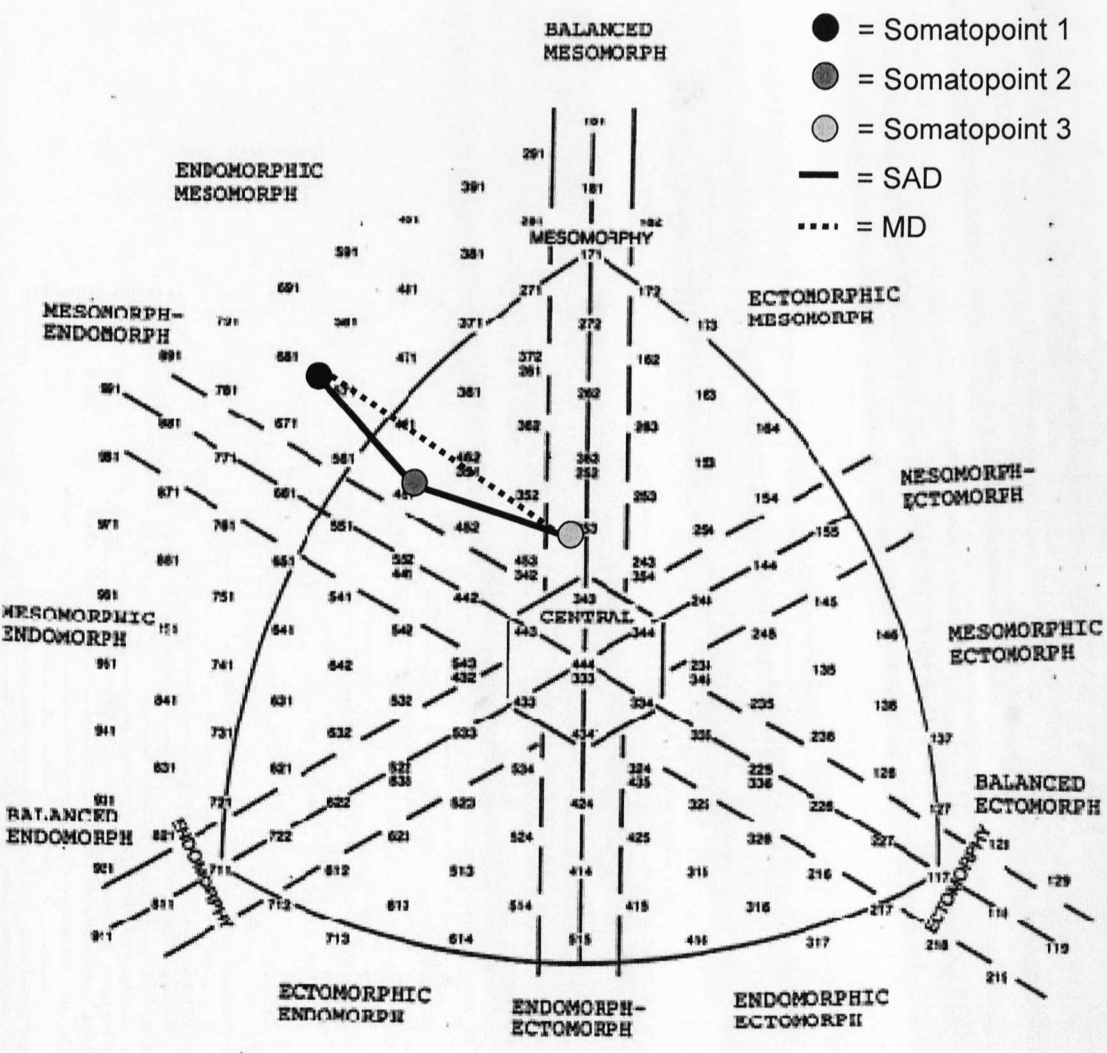


Figure 3.5. 2-D somatochart showing co-ordinates and somatotype categories (Norton & Olds, 1996) with 3 example somatopoints plotted to illustrate SAD and MD.
SAD = Somatotype Attitudinal Distance MD = Migratory Distance

Using appropriate equations (Box 3.3) the distance between somatotypes can be quantified in two or three dimensions (Marfell-Jones et al., 2006). Two and three dimensional distances between pairs of somatotypes are called the somatotype dispersion distance (SDD) and somatotype attitudinal distance (SAD), respectively. The average of the distribution of somatotypes about their mean can also be calculated in two dimensions (somatotype dispersion mean; SDM) and three dimensions (somatotype attitudinal mean; SAM) (Carter & Heath, 2005).

The three-dimensional approach is recommended for most analyses as SAD and SAM contain more accurate information about the true distances between somatotypes than the SDD and SDM (Marfell-Jones et al., 2006). The SAD is the exact difference, in component units between two somatotypes (A, an individual or group, and B, an individual or group), or between a subject and a group mean (e.g. subject A and group mean B) (Duquet & Carter, 2009). In this study, A and B were the same individual between two time points, for example from baseline to month 2 (Box 3.3). The migratory distance (MD) is a quantitative way to describe the total change in somatotype over time. This is calculated by summing SAD values, calculated from each consecutive pair of somatotypes of the subject. For example in this study, the sum of change in somatotype from baseline to month 2, month 2-3 and month 3-4.....month 11-12. (Box 3.3).

A number of parametric and non-parametric techniques can be applied to analyse somatotype data, however not all are appropriate for every study (Marfell-Jones et al., 2006) and exact procedures of analysis are determined by the nature of the data, the numbers of subjects and the kinds of groups to be compared (Carter & Heath, 2005). Carter and Heath (2005) recommend the use of descriptive statistics and a somatochart as a minimum for any study involving somatotype data. Therefore, the studies within this thesis will present somatotype category distributions and somatocharts alongside descriptive data including mean endomorphy, mesomorphy and ectomorphy ratings, and SAM, SAD and MD values. To test for differences between the

distributions of somatotype category between samples, Chi-square test can be applied (Carter & Heath, 2005). However Chi-square test cannot be used in a repeated measures design and there are no universally-accepted 'post-hoc' with categorical tests. Thus this procedure is unsuitable to the analysis aims of the studies that comprise this thesis and were not utilised.

$$SAD(A; B) = \sqrt{(\text{end}(A) - \text{end}(B))^2 + (\text{mes}(A) - \text{mes}(B))^2 + (\text{ect}(A) - \text{ect}(B))^2}$$

(Where SAD = somatotype attitudinal distance; A and B = same individual at two different time points; end = endomorphy; mes = mesomorphy; and ect = ectomorphy)

$$SAM(X) = \sum_i \frac{SAD(\bar{X} - X_i)}{N_X}$$

(Where SAM = somatotype attitudinal mean; SAD = somatotype attitudinal distance; X = a group; \bar{X} = somatotype mean of group; X_i = an individual member of a group; N_X = number of participants in group X)

$$MD(a; z) = SAD(a; b) + SAD(b; c) + \dots + SAD(y; z)$$

(Where a = first observation, b = second observation; ..., z = last observation; SAD(p; q) = change from somatotype p to somatotype q)

Box 3.3. Equations to derive somatotype attitudinal distance (SAD), somatotype attitudinal mean (SAM) and migratory distance (MD) (Carter & Heath, 2005).

To compare between two or more somatotypes in a repeated measures design analysis of variance (ANOVA) using SAD values calculated for each individual can be used (Carter & Heath, 2005). These values do not give the actual direction of change, thus somat charts are used to identify direction (Carter, personal communication, 2010). Therefore, in all studies, analysis of global somatotype in three-dimensional space was calculated by plotting the mean somatotype (\bar{S}) at each month on a somat chart, and calculating each individuals SAD between each month. MD was also calculated to examine changes over longer time periods. A repeated measures analysis of variance

(ANOVA) was used to compare the mean somatotypes, using the calculated SAD scores. Bonferonni multiple comparison procedure was applied to determine which means were different, using a critical value of 0.49 SAD units. This value is considered a meaningful and practical difference between somatotype means (Carter et al., 1997). If there were changes over time, each individual component was tested using repeated measures ANOVA to see which changed significantly.

4. STUDY ONE: Longitudinal change in anthropometric measures

This chapter examines the change in a range of anthropometric measures in an overweight/obese population, actively trying to lose weight, in order to identify the most discernible measure of change. Data are presented in two parts. Part A first examines the changes in both traditional and alternative body composition measures over a 4 month period. This was to establish whether these measures changed significantly in the short-term, thus justifying longitudinal investigation. Long-term outcomes may provide more information about the sustainability of these anthropometric measures as tools to monitor weight loss over time. Therefore, part B examined and compared change in traditional and alternative anthropometric measures over an extended time period of a year, in order to identify whether alternative anthropometric measures showed greater magnitudes of change than traditional anthropometric measures. This chapter also includes consideration of the controversies surrounding the measurement of change and the issues associated with unit variation when analysing and comparing variables. This was an issue in the current study and various analysis methods are discussed and justification provided for the choice of analysis used in the data analysis conducted in part B.

4.1 Introduction

Establishing the best technique to measure obesity has long been a matter of dispute (Franzosi, 2006; James, 2005). Weight related parameters, such as body weight and BMI, are the most commonly used methods to determine obesity status and define success within weight management programmes (Carmichael, 1999). However, the limitations of these measures are well documented (Norton & Olds, 1996; Cook et al., 2005; Blair & LaMonte, 2006). The composition of the body; comprising of lean body tissue and body fat or adipose tissue, is an important factor to consider when assessing

obesity and health status. Both the total amount of body fat and the way in which fat is regionally distributed affect the risk and severity of many chronic diseases (Heyward & Wagner, 2004). For example, independent of BMI, both cross-sectional and longitudinal studies have related central fat to T2DM and CVD (Pi-Sunyer, 2004). Furthermore, health benefits are often seen independent of weight loss. This is highlighted in a study by Lee et al. (2005) who found that regular exercise without weight loss was associated with a substantial reduction in total and visceral fat and in skeletal muscle lipid in both obesity and T2DM. A summary statement from the American Heart Association authored by Poirier et al., (2006) acknowledges the lack of prospective trials that show change in mortality with weight loss in obese patients, studies have reported that individuals who intentionally try to lose weight present significantly lower all cause mortality, independent of weight change. For example, in a sample of 6391 overweight and obese individuals ($\text{BMI} \geq 25 \text{ kg.m}^{-2}$) aged at least 35 years, Gregg et al. (2003) reported 24% lower mortality rates in those reporting intentional weight loss compared to persons not trying to lose weight and reporting no weight change. A 31% higher mortality rate was observed in those with unintentional weight loss compared to persons not trying to lose weight and reporting no change. Furthermore, in a prospective analysis with a 12-year mortality follow-up of 4,970 overweight individuals with diabetes, aged 40-64 years, intentional weight loss was associated with a 23% reduction in mortality (Williamson et al., 2000). However, the reasons for weight-change in these studies are unclear and do not permit any assumptions of causality. In order to determine the true effect of weight loss on mortality, more long-term prospective studies are needed.

In light of the recognition that fat distribution, independent of overall obesity, is associated with metabolic disturbances and increased disease risk (Snijder et al., 2006) the need for improved measures of body fat and fat distribution has been recognised (Deitel et al., 2007). In particular these improved analytical methods should be sensitive to intra-individual change (Teixeira et al., 2005). The method of somatotyping combines an appraisal of

relative adiposity, musculo-skeletal robustness and linearity into a three number rating – summarising the physique as a unified whole (Kaur, 2009; Gakhar & Malik, 2002). As a consequence of this uniqueness, somatotyping has been used to study many aspects of exercise, sports sciences and human biology (Carter et al., 2005). It has been used to describe and compare the physiques of athletes at all levels of competition and in a variety of sports. It has also been used to describe the changes in physique during growth, ageing and training, as well as in relation to physical performance (Duquet & Carter, 2001). However the use of somatotyping in an overweight/obese population has to date received little attention. Even the limited somatotype surveys of the general population that have been conducted are unlikely to reflect the incidence of obesity because the obese generally avoid such exposure (Carter & Heath, 2005).

In a study by Fett et al., (2006) somatotype data were collected on overweight or obese sedentary women assigned to either a circuit training (n=14), or jogging intervention (n=12). The mean BMI of the circuit training group and jogging group at baseline was $33 \pm 8 \text{ kg.m}^{-2}$ with mean endomorphy, mesomorphy and ectomorphy scores of 10.0-7.0-0.6, respectively. In comparison the jogging group (n=12) had a mean BMI of $28 \pm 1 \text{ kg.m}^{-2}$ at baseline with mean endomorphy, mesomorphy and ectomorphy scores of 9.0-5.0-0.4 respectively. These endomorphy and mesomorphy scores are higher than those observed in a study by Seltzer and Mayer (1969), cited by Carter and Heath (2005), who identified mean somatotype ratings of 8.5-4.5-1.0 in a population of 90 adult, obese Caucasian women, aged 24-70 years and 61.7kg – 155.5kg. The circuit training group showed a significant reduction in endomorphy from month one to month two, decreasing from 10 to 8. Mesomorphy and ectomorphy showed no significant change. In contrast, the jogging group showed significant change in all somatotype sub-components from baseline to month 2 (9.0-5.0-0.4 and 7.0-5.0-1.5, respectively).

As exclusive or excessive focus on weight as an outcome is a recognised limitation of current research (Teixeira et al., 2005) Study One aimed to compare the discernibility of traditional and alternative anthropometric measures. In order to increase the likelihood of change occurring, both parts A and B of the current study focused on change in overweight/obese individuals actively trying to lose weight. As the study aimed to identify the most discernible measure to monitor change, identifying this within the population that it would be most likely used (i.e. monitoring weight loss of individuals over their ideal weight) was deemed most appropriate. Part A first examined these changes over a 4 month period.

4.2 PART A

4.2.1 Aims and hypotheses

Part A of Study One aimed to examine the change in traditional and alternative body composition measures within an overweight/obese population over a four month period. No comparison was made between traditional and alternative anthropometric measures at this stage as the aim was solely to identify whether significant changes occurred, in order to warrant further investigation. The following alternative (experimental) hypotheses were formulated:

H₁) Alternative anthropometric measures would change significantly over a 4 month period.

H₂) Traditional anthropometric measures would change significantly over a 4 month period.

4.2.2 Methods

4.2.2.1 Study design & participants

The fundamental design of Study One was a longitudinal prospective study consisting of a cohort group. Cohort studies do not have randomisation of study participants therefore they are more vulnerable to selection bias and may affect the reliability and validity of results. However, in the current study no intervention was given as each participant acted as their own control. For example, all participants received the same treatment (body composition assessment) regardless of what diet or exercise programme they may have been following. The change in one anthropometric measure was compared with the change in another anthropometric measure of that same individual. Thus the vulnerability of selection bias, common in cohort studies (Rochon et al., 2005), was controlled in the current study. Furthermore cohort study data

permits the longitudinal observations of an individual through time (Tager, 1998), thus temporal relations can be clarified (Sabin & Phillips, 2001). As Part B of Study One focused on longitudinal observations, cohort data suited the nature of the study's aims and objectives.

Participants were recruited via distribution of leaflets and posters at GP surgeries within the Portsmouth area, poster advertising in local fitness facilities, and presentations at local slimming organisations and community groups in the Portsmouth area. All studies that comprise this thesis ran concurrently and Appendix 5 provides a flowchart to denote participants' progression through the studies.

Potential participants were invited to an orientation session where height and mass were confirmed and the study objectives and design were explained and a participant information sheet provided (Appendix 6). Inclusion criteria consisted of a BMI >24.9 , actively trying to lose weight, and satisfactory completion of the relevant physical activity readiness-questionnaire (PAR-Q) and consent form (Appendices 7 and 8, respectively). Participant's approaches to weight loss included following commercial slimming programmes, organised walking programmes and self-directed diet and exercise programmes. If participants' resting heart rate (HR) or blood pressure (BP) were above pre-determined thresholds of 90bpm (heart rate), 150mmHg (systolic BP) or 90mmHg (diastolic BP), GP approval for the participants involvement was sought (Appendix 9). Participants were male or female, between the ages of 15-75 years. Written informed consent was obtained from each participant and kept on file. An *a priori* power analysis revealed that a sample size of 100, with an *a priori* alpha level of 0.05 would yield a power ($1-\beta$) of 0.9539 (two-tailed test) or 0.9778 (one-tailed test).

4.2.3 Procedures

Level I restricted profiles were conducted on 90 participants (male n=17, female n=73) on a monthly basis over a 4 month period. Using the internationally recognised BMI classification system, participants were classified as overweight (n=27), obese (n=34) or morbidly obese (n=29). Resting HR and BP, measured whilst seated, were also collected monthly. All data were collected following the protocols detailed in Chapter 3.1. The mean time between each measurement session is shown in Table 4.1. All participants were asked to complete a 3 day food and exercise diary between each measurement session (Appendix 10).

Table 4.1. Mean (\pm SD) time (days) between measurement sessions over four month testing period.

Mean (\pm SD) time between measurement sessions (days)			
Baseline and month2	Month 2 and 3	Month 3 and 4	Baseline and month 4
33.8 \pm 6.0	31.9 \pm 5.6	33.9 \pm 6.0	99.3 \pm 11.0

4.2.3.1 Statistical analyses

4.2.3.1.1 Tests of normal distribution

All statistical analyses were performed using Predictive Analytic Software (PASW) statistics computer package, with an alpha level of 0.05 for all statistical tests. Initially distribution of data were analysed through examination of histograms, evaluation for skewness and kurtosis, and more formally through the Shapiro-Wilk and Kolmogorov-Smirnov test statistic. Homogeneity of variance was also examined through Levene’s test. All anthropometric variables were normally distributed.

4.2.3.1.2 Tests of difference

The frequency of somatotype by category were examined and the SAD (between months) and MD (over the four month period) calculated. To identify the change in anthropometric variables, a within subjects Wilk's Lambda multivariate repeated measures ANOVA, with Bonferonni adjustment was conducted, with time as an independent factor and BMI, body mass, WHR, %BF, Σ 8SF, SAM, SAD, MD and the individual somatotype sub-components; endomorphy, mesomorphy and ectomorphy, as dependent variables.

Since the variables being compared were calculated from the same set of anthropometrical measuring points, it was possible that some would influence others therefore checks for covariance were made. Mauchly's test indicated that the assumption of sphericity had been violated. Therefore when examining month on month change, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. When examining residual plots, no variables appeared to be influencing or were being influenced by other variables.

4.2.4 Results

Results are presented for a total of 90 participants who attended all measurement sessions. Baseline demographic and anthropometric measures are provided in Table 4.2. Figure 4.1 provides a breakdown of the dietary methods/services utilised by participants at baseline. Over half of all participants followed their own healthy eating plan (55%), with the remainder following commercial slimming programmes (most commonly Weight Watchers (18%) or Slimming World (11%)) or receiving dietetic support (4%). Data was unavailable for 9% of participants.

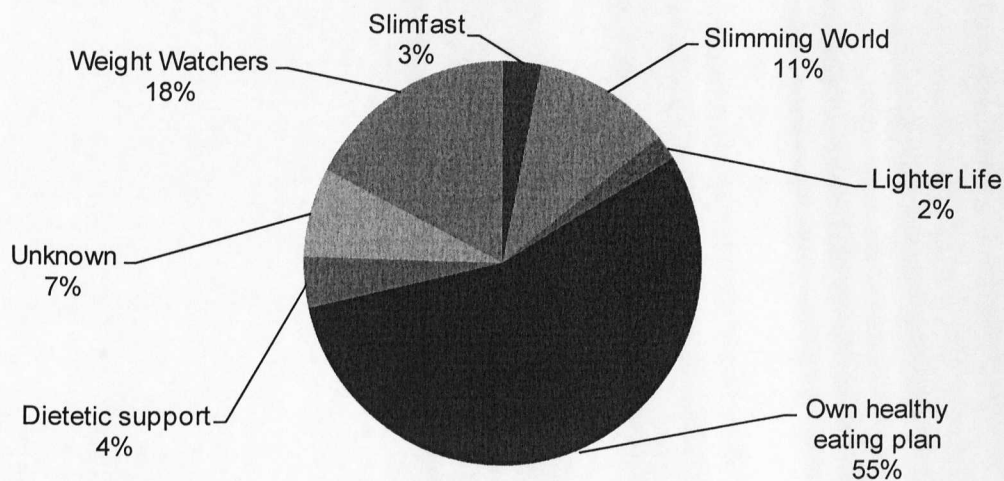


Figure 4.1: Breakdown of current dietary methods/services utilised by participants (n=90) at baseline.

Figure 4.2 provides a breakdown of the physical activity and exercise methods/services utilised by participants at baseline. Almost half of participants were members of a leisure facility (45%), accessing the gymnasium and/or exercise classes. 29% were members of a local walking group with an additional 9% of participants also accessing exercise classes in addition to membership of the walking group. 17% of participants followed their own exercise plans. Data was unavailable for the remaining 9% of participants. Further data regarding participants' diet and exercise habits as they progressed throughout the study are not presented due to non-compliance of participants filling out monthly food and exercise diaries.

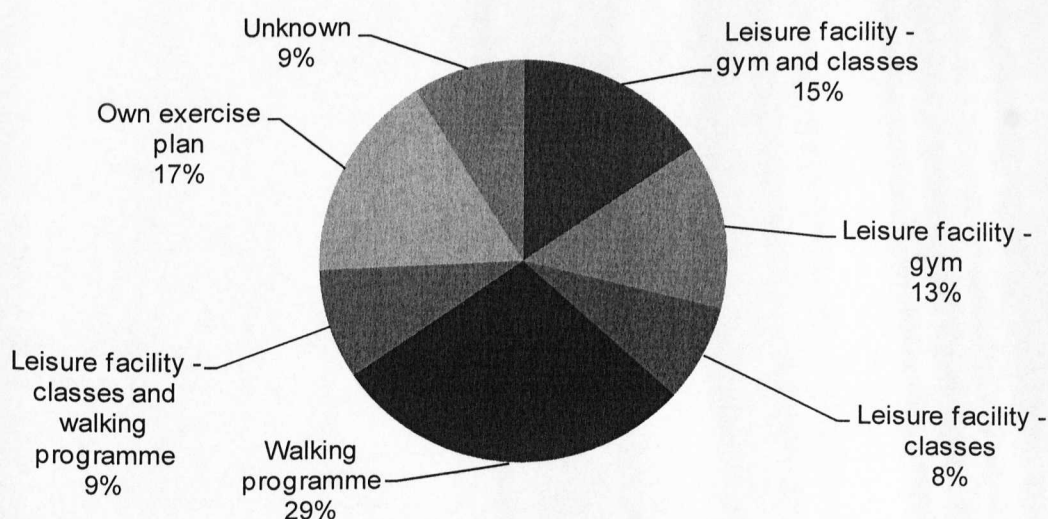


Figure 4.2: Breakdown of current physical activity methods/services utilised by participants (n=90) at baseline.

Figure 4.3 represents the group distribution of all participants, based on their individual somatotype evaluation at baseline and at month 4. Of the possible 13 somatotype categories, all examined participants fell into three categories; mesomorph-endomorph, endomorphic mesomorph, and mesomorphic endomorph.

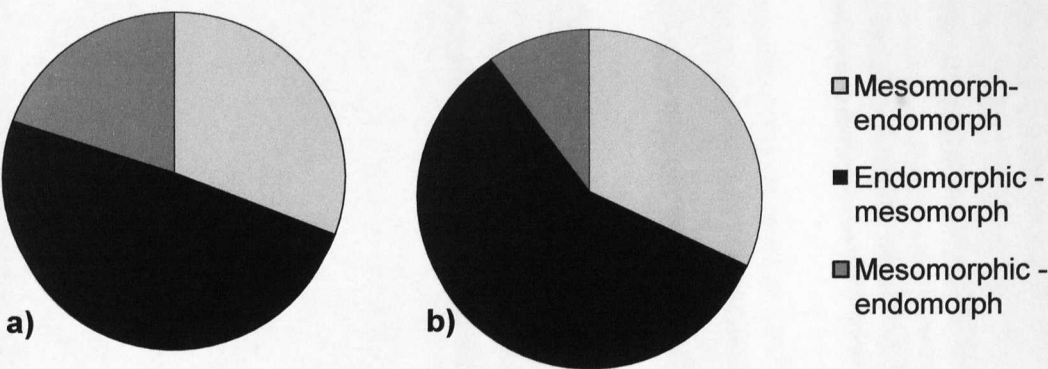


Figure 4.3. Somatotype distribution of participants (n=90) at baseline (a) and month 4 (b).

The proportion of participants classified as mesomorph endomorphs was almost identical at baseline (31%) and month 4 (32%), respectively (Fig. 4.1). Almost half of participants (49%) were classified as endomorphic-mesomorphs at baseline and this increased to 58% at month 4. The reverse was seen in the proportion of mesomorphic endomorphs reducing to 10% at month 4, from 20% at baseline.

Table 4.2. Mean (\pm SD) baseline demographic measures and traditional and alternative anthropometric measures for all participants involved in Part A of Study One (n=90), including breakdown by gender and BMI classification*.

	Male (n=17)	Female (n=73)	Overweight (n=27)	Obese (n=34)	Morbidly Obese (n=29)	All (n=90)
Age (years)	51.9 \pm 17.2	49.8 \pm 15.5	52.8 \pm 15.0	50.6 \pm 16.7	47.4 \pm 15.3	50.2 \pm 15.7
Height (cm)	176.6 \pm 7.5	163.2 \pm 6.1	173.4 \pm 7.9	162.8 \pm 6.3	162.4 \pm 5.9	165.9 \pm 8.3
Mass (kg)	102.5 \pm 22.8	88.9 \pm 16.3	77.3 \pm 7.2	86.8 \pm 8.1	110.2 \pm 16.4	91.6 \pm 18.3
BMI (kg.m ⁻²)	32.8 \pm 6.6	33.4 \pm 5.8	27.4 \pm 1.1	32.2 \pm 1.4	39.8 \pm 5.3	33.2 \pm 5.9
WHR	1.0 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	1.0 \pm 0.1	0.9 \pm 0.1
BF (%)	26.6 \pm 6.0	36.7 \pm 3.5	29.9 \pm 6.2	35.8 \pm 3.8	38.3 \pm 3.5	34.8 \pm 5.7
Σ 8SF (mm)	166 \pm 68	215 \pm 42	155 \pm 39	207 \pm 35	249 \pm 37	205.6 \pm 52.3
Endomorphy	5.3 \pm 1.6	7.0 \pm 1.1	5.2 \pm 1.3	6.8 \pm 0.8	7.7 \pm 0.8	6.6 \pm 1.4
Mesomorphy	6.9 \pm 1.7	7.6 \pm 1.8	5.7 \pm 0.8	7.3 \pm 1.0	9.2 \pm 1.6	7.4 \pm 1.8
Ectomorphy	0.5 \pm 0.6	0.2 \pm 0.3	0.7 \pm 0.5	0.1 \pm 0.1	0.1 \pm 0.0	0.3 \pm 0.4

*as defined in Table 2.1

Due to the small changes in global somatotype between months only the mean somatotype at baseline and month 4 are plotted on the somatochart (Fig. 4.4) to aid visualisation. The differences between the scatter of somatotypes about their means (SAMs) at baseline and month 4 did not differ, with a narrow range of 1.9-2.0 ($F=1.22_{,3,87}, P>0.05, \text{Eta}^2=0.04, 1-\beta=0.3$). When the whole somatotype means were compared, significant differences were observed ($F=206.405_{,3,57}, P<0.05, \text{Eta}^2=0.699, 1-\beta=1.00$). No significant change in somatotype means were observed between months (SAD), however the change from baseline to month 4 was significant ($\text{MD}=0.8\pm0.05, P<0.05$). The mean somatoplots in Figure 4.4 reflect this difference as they move from left to right across the somatochart.

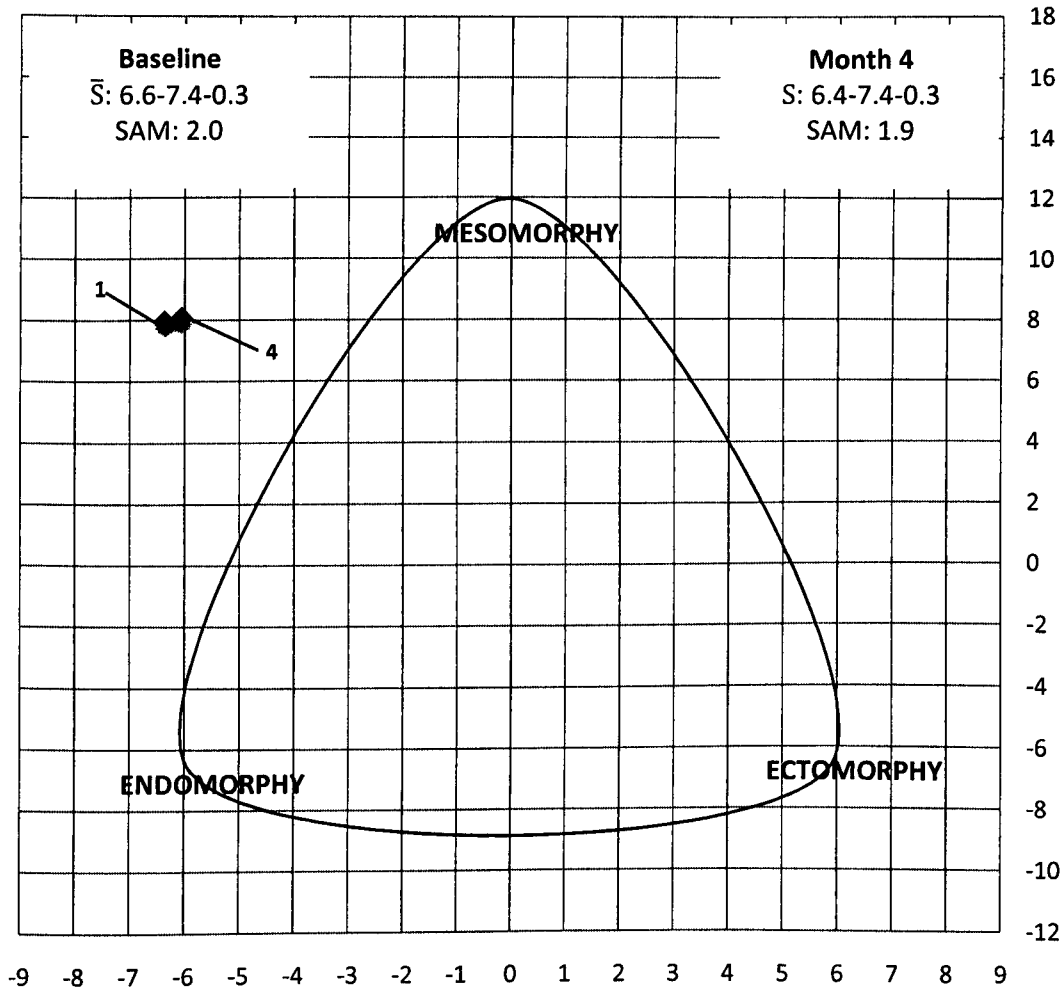


Figure 4.4. Mean somatotype (n=90) for baseline and 4.

* \bar{S} = mean somatotype, SAM=somatotype attitudinal mean

Examination of anthropometric variables, including individual somatotype component ratings, identified significant change over time ($F=4.4098_{,24,741}, P<0.05, \text{Eta}^2=0.667, 1-\beta=1.00$). Within the alternative anthropometric measures $\Sigma 8\text{SF}$ showed a significant mean decrease of $15.4\pm 2.1\text{mm}$, endomorphy showed a significant mean decrease of 0.29 ± 0.04 and ectomorphy showed a significant mean increase of 0.03 ± 0.01 (Fig. 4.5). Of the traditional measures, BMI, mass and %BF showed significant change, decreasing by $0.6\pm 0.1\text{kg.m}^{-2}$, $1.5\pm 0.4\text{kg}$ and $1.0\pm 0.2\%$, respectively (Fig. 4.6).

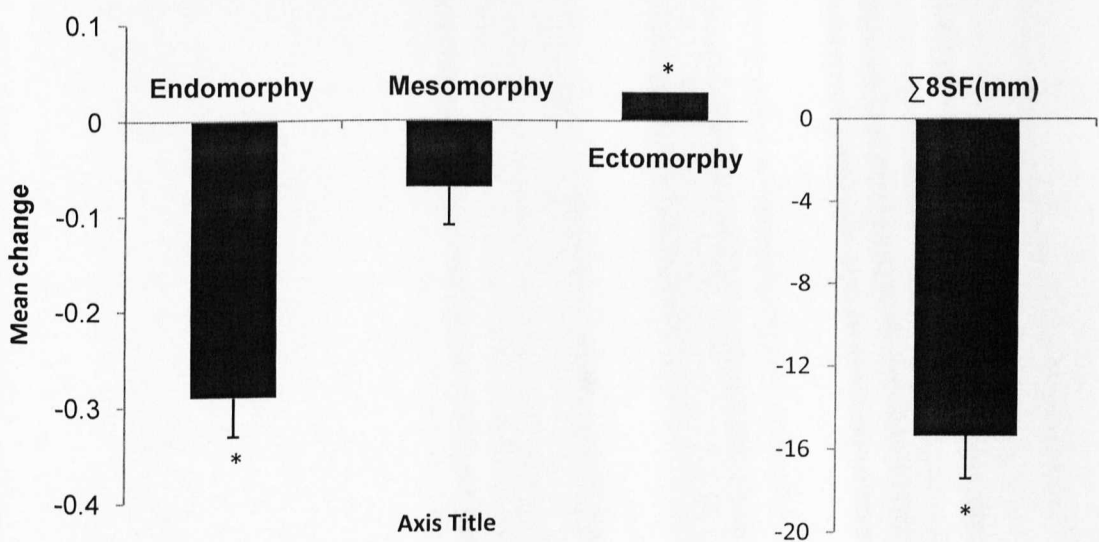


Figure 4.5. Mean change of alternative anthropometric measures from baseline to month 4 (n=90).

* $P<0.05$

Vertical bars show standard errors of the mean

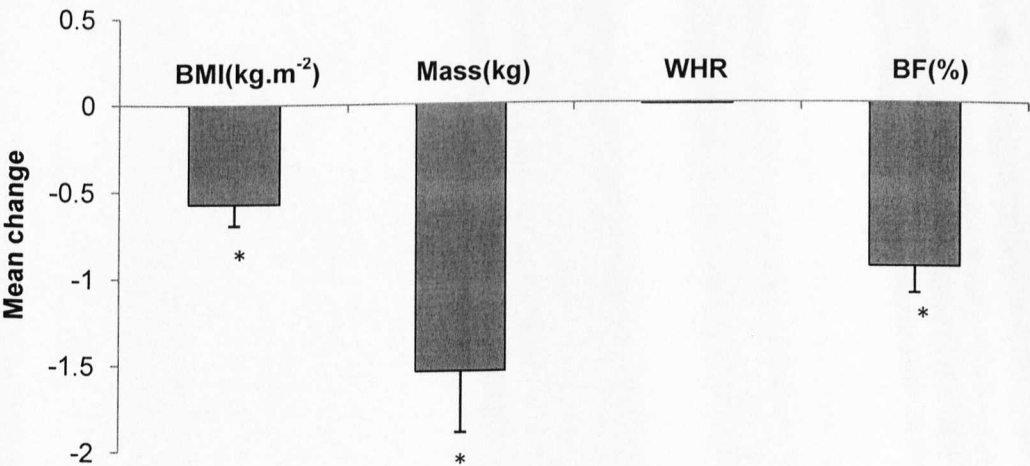


Figure 4.6. Mean change of traditional anthropometric measures from baseline to month 4 (n=90).

* $P<0.05$

Vertical bars show standard errors of the mean

When examining month on month change within alternative anthropometric measures, Σ 8SF and endomorphy show significant change at all time points (Table 4.3). In contrast, whilst ectomorphy showed significant change over the four month period pre and post (Fig. 4.5), the only significant change that was observed between months was a mean 0.02 ± 0.01 decrease between months 3 and 4. No significant changes were observed between months in mesomorphy. Within traditional measures, %BF changed significantly at all time points, BMI and mass showed significant change between some months but not others and WHR showed no significant change between any months (Table 4.3).

Table 4.3. Mean change of traditional and alternative anthropometric variables between months (n=90).

	Δ Baseline - month 2	Δ Month 2-3	Δ Month 3- 4	Δ Baseline – month 4
TRADITIONAL				
BMI (kg.m ⁻²)	-0.31 \pm 0.06*	-0.22 \pm 0.06	-0.04 \pm 0.06	-0.57 \pm 0.12*
Mass (kg)	-0.83 \pm 0.19*	-0.62 \pm 0.17*	-0.10 \pm 0.17	-1.54 \pm 0.35*
WHR	-0.01 \pm 0.00	-0.01 \pm 0.00	-0.01 \pm 0.00	-0.02 \pm 0.00
BF (%)	-0.32 \pm 0.09*	-0.38 \pm 0.08*	-0.23 \pm 0.07*	-1.00 \pm 0.15*
ALTERNATIVE				
Σ 8SF mm)	-5.22 \pm 1.36*	-5.84 \pm 0.86*	-4.28 \pm 0.87*	-15.4 \pm 2.06*
Endomorphy	-0.11 \pm 0.03*	-0.11 \pm 0.02*	-0.07 \pm 0.02*	-0.29 \pm 0.04*
Mesomorphy	-0.04 \pm 0.02	-0.03 \pm 0.02	-0.01 \pm 0.02	-0.07 \pm 0.04
Ectomorphy	0.01 \pm 0.01	0.01 \pm 0.01	0.02 \pm 0.01*	0.03 \pm 0.01*
SAD	0.3 \pm 0.02	0.2 \pm 0.02	0.2 \pm 0.02	-
MD	-	-	-	0.8 \pm 0.05*

*P<0.05
Values rounded to two decimal places

In summary global somatotype means showed significant change from baseline to month 4 (Fig. 4.4) and examination of individual component ratings identified that endomorphy decreased significantly over this time period and ectomorphy increased (Fig. 4.5). Furthermore, Σ 8SF also showed a significant decrease from baseline to month 4, and also showed significant

change between months, as did endomorphy (Table 4.3). Thus H_1 , that alternative anthropometric measures would show significant change over time, is supported for all alternative anthropometric measures with the exception of mesomorphy. BMI, mass and %BF all showed significant change from baseline to month 4 (Fig. 4.6) and %BF also showed significant change between months. Thus H_2 , that traditional anthropometric measures would show significant change over time, is supported for all traditional anthropometric measures with the exception of WHR.

4.2.4 Discussion

The results reported indicate that collectively both traditional and alternative anthropometric variables show change over a 4 month period (Fig. 4.4 - 4.6). However when examining change month on month differences are apparent in the traditional and alternative anthropometric measures, with some demonstrating significant change every month and others at some time points but not others (Table 4.3). For example, endomorphy showed significant decreases at every monthly interval over the 4 month period, indicating a positive change in the composition of the body in that relative fatness decreased over time. In contrast BMI showed a significant decrease only in the initial stages, between months one and two, then no further significant change was evident.

Weight maintenance seems to require an ongoing adherence to weight-related behaviours (Elfhag & Rossner, 2005). Moderate to large levels of attrition are frequent in many published studies in the area of obesity and retention over time remains a challenge (Goldberg & Kiernan, 2004). For example, reported attrition rates in obesity studies range from 20-45% (Clark et al., 1996) with others reporting rates as high as 80% (Farley et al., 2003). A study of 80 women randomly assigned to a commercial weight reduction program or a control group reported 12 week attrition rates of 25% and 65%, respectively (Rippe et al., 1998). More recently in a study of 160 people comparing the effectiveness of four popular diets, attrition rates were 21%

and 34% by months 2 and 6 respectively (Dansinger et al., 2005). Other studies involving obese patients enrolled in weight loss programs and treated for an average of 26 weeks report attrition rates from 19 to 56% (Anderson et al., 1994; Wadden et al., 1992; Walsh & Flynn, 1995). These results may have important implications. From a feedback perspective, focusing on measures that do not change readily or do not adequately reflect changes in body composition may be discouraging and de-motivating to an individual, leading to increased drop-out from weight management programmes.

Pertinent to this is the common occurrence of weight regain. Pronounced initial weight loss may illustrate the successful start in carrying out the decision to lose weight (Elfhag & Rossner, 2005), however weight regain is a common occurrence which can affect individual’s motivation and self-efficacy (Ulen, 2008; Warziski, 2007). Figure 4.7 shows the weight regain patterns in participants following a structured commercial weight loss programme and those in a control group following self-directed weight loss programmes (Heshka et al., 2003). Whilst a statistically significant weight loss was found in the commercial weight loss programme, at 26 weeks both groups started to regain weight. At the end of the 2 years the control group has almost returned to their initial starting weights with only 16% of the commercial weight loss group maintaining a loss of 10 % or their initial body weight.

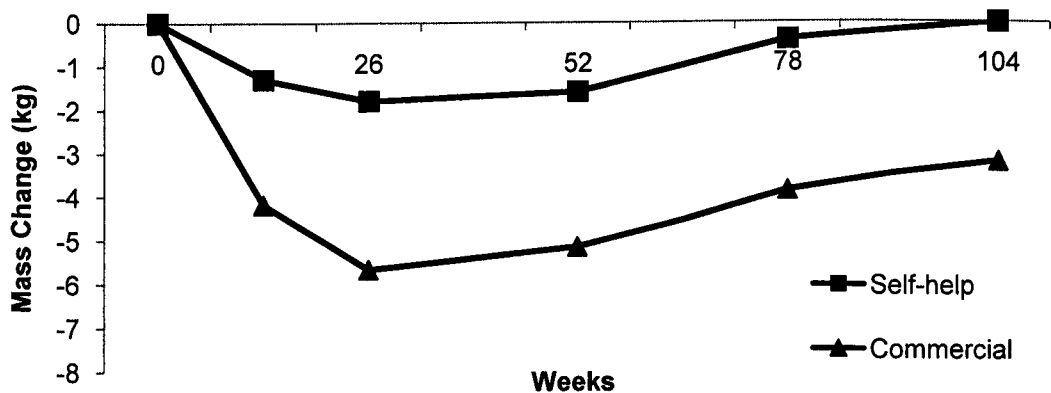


Figure 4.7. Weight change (kg) in self-help group vs. commercial weight management programme over a 2 year period (Heshka et al., 2003).

Gardner et al. (2007) compared 4 common diets in 311 overweight/obese women over a 12 month period and also showed evidence of weight regain. Most weight loss occurred within the first two months, with no visible change for three of the four diets between months 2 and 6 (Figure 4.8). Weight regain occurred in all groups after 6 months.

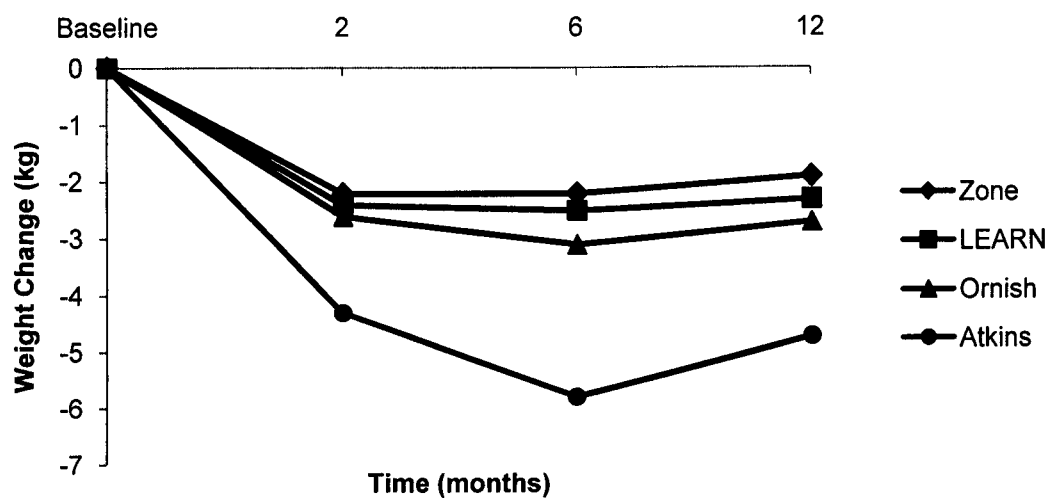


Figure 4.8. Weight loss patterns in 4 diet groups over 1 year (Gardner et al., 2007).

When examining post-treatment weight change over a 12 month period following a 16-week activity intervention, Andersen et al. (2001) found similar patterns of weight regain (Figure 4.9). Participants that attended quarterly follow up meetings (n=33) were classified in to one of three activity groups according to the percentage of weeks that met or exceeded the Surgeon general's guidelines for physical activity in the year after completion of treatment. No differences in weight regain were apparent between activity groups at months 3 and 6 however by month 9 the least active group had regained significantly more weight than the most active group, which by contrast had lost weight (Figure 4.6). From month 9 all activity groups experienced weight regain with the middle active group returning to near baseline levels and the most active group experiencing a 1.2kg regain from month 9 to month 12 (Andersen et al., 2001).

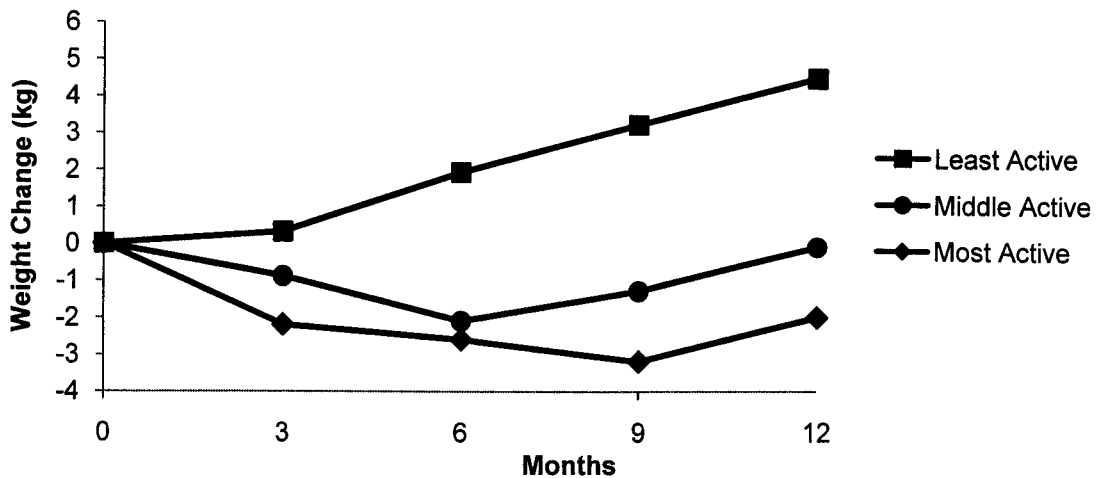


Figure 4.9. Post-treatment weight change in 3 activity groups over 1 year (Andersen et al., 2001).

The significant weight loss of 1.5 ± 0.4 kg over 4 months in the current study (Fig. 4.6) is less than the 2.3-5.2 kg losses observed by Gardner et al. (2007) over the same time period. An explanation for this could be that the participants involved in the present study were following self-directed programmes as opposed to structured diet programmes followed in the study conducted by Gardner et al. (2007). For example, at 16 weeks the weight loss observed in the self-help control group in the study conducted by Heshka et al. (2003) was 1.5 kg, comparable to the present study results, thus providing support for this explanation.

Although changes in body mass and BMI have been examined over 12 months (Andersen et al., 2001; Berkowitz et al., 2003; Doshi et al., 2009; Gardner et al., 2007; Heshka et al., 2003) less is known about the changes in other anthropometric measures such as somatotype scores over this longer time period. Isolating the individual importance of each anthropometrical variable may facilitate the understanding of the most appropriate measure to be used at specific time points as a successful strategy for weight loss maintenance. Additionally, it is well documented that health benefits can occur in the absence of weight loss and many studies have documented changes in body composition despite no concurrent

changes in body mass and BMI (Lee et al., 2005). For example, in a sample of 15 healthy obese women aged 35 ± 9.8 years, with a BMI of $36.4 \pm 7.1 \text{ kg.m}^{-2}$ Ross et al. (1993), found a significant 16.8 cm^2 decrease in visceral adipose tissue despite a non-significant weight loss of 0.5kg. Error values reported by Ross et al., (1993) for the measurement of visceral and subcutaneous fat in the study were just 5.5% and 1.1%, respectively, highlighting the quality of this research. More recently Hunter et al. (2002) in a study on elderly individuals involved in resistance training, found a significant mean decrease of 9.2kg of fat mass, however no significant decrease in body mass.

The results of the current study suggest that positive changes in the composition of the body occurred every month, as illustrated by the significant decreases shown in $\Sigma 8\text{SF}$, endomorphy and %BF at every monthly interval (Table 4.3). Body mass and BMI also showed positive changes, however these anthropometric measures only demonstrated significant change between baseline and month 2 (BMI and mass) and months 2 and 3 (mass only). Retrospective studies of successful weight maintainers, defined as an initial weight loss that has been subsequently maintained for at least 6 months, have shown that individuals who successfully maintain lower body weights, particularly women, show more concern with shape and appearance (Elfhag & Rossner, 2005). Thus utilising non weight related parameters that focus on body shape/composition may further contribute to successful weight loss and maintenance.

Studies reporting weight losses of 6-13kg over 6 months in women (Pascale et al., 1992); and 9-16kg over 6 months in men (Pascale et al., 1992; Wing et al., 1992) have reported concurrent changes in WHR of 0.01 – 0.02, and 0.04, respectively. In contrast, in a comparison of four commercial weight loss programmes, Gardner et al., (2007) reported no significant change in WHR in any of the four weight loss programmes, despite significant weight losses. The results of the present study indicate no statistically significant change in WHR from baseline to month 4 (Fig. 4.6) or between months (Table 4.3). Wing et al. (1992) reports no association between weight loss

and change in WHR when weight loss is below 6.8kg, therefore the non-significant changes in WHR may be due to the smaller changes in body mass of <2kg in the present study.

The somatotype sub-component mesomorphy (that relates to relative muscularity) showed no significant change over the four month period (Fig. 4.5). Weight training exercise has been found to facilitate body fat loss and can preserve or increase fat-free mass (Ballor & Keeseey, 1991). In a comparison of the effects of structured aerobic activity and moderate lifestyle activity on weight loss Andersen et al. (1999) found that the aerobic group lost significantly less fat-free mass (0.5kg) than the lifestyle group (1.4kg). Energy expenditure accounts for much of the variance associated with changes in fat-free mass (Ballor & Keeseey, 1991) and the fact that the participants in the present study were not following structured exercise programmes may explain the negligible change in mesomorphy over the four months.

With regard to the ectomorphy somatotype sub-component, significant change was observed from baseline to month 4 (Fig. 4.5), however between months a significant increase was only observed between months 3 and 4 (Table 4.3). Fett et al. (2006) observed that ectomorphy was positively related to the skeletal factor and negatively related to the muscular factor and body fat. It is not a tissue-based measure but a ratio of mass to stature and as such gives no direct body composition information. Therefore the minimal variation of ectomorphy in the present study ($\Delta = 0.03 \pm 0.01$) is in line with expectations. Carter and Heath (2005) suggest it is better to consider the criterion body composition variables to be endomorphy and mesomorphy.

4.2.5 Conclusion

The results of Study One, Part A indicate that both traditional and alternative anthropometric measures used to monitor change in overweight and obese individuals, showed significant change over a four month period with the exception of mesomorphy and WHR (Fig. 4.4-4.6). When examining month on month change, differences between the measures were observed, with %BF, Σ 8SF and endomorphy showing significant change more frequently than BMI, Mass, WHR, mesomorphy and ectomorphy (Table 4.3). Therefore it is concluded that traditional and alternative anthropometric measures show significant change and H₁, that alternative anthropometric measures would show significant change over a four month period is accepted for all measures, excluding mesomorphy. H₂, that traditional anthropometric measures would show significant change over a four month period is accepted for all measures, excluding WHR.

It is well known that individual change takes place continuously over time and repeated anthropometric measures allow the continuous process of human change to be documented effectively (Willet, 1995). Having established that the traditional and alternative anthropometric measures showed significant change over a four month period, and varied in their change at specific time points, further analysis was warranted over a longer-time period in order to inform their utility as tools to evaluate weight loss success. Thus Part B of Study One examined and compared the change in the traditional and alternative anthropometric measures over a longer time-period.

4.3 PART B

4.3.1 Aims and hypotheses

The aim of Study One, Part B was to compare the change in traditional and alternative anthropometric measures within an overweight/obese population over an extended time period of a year. More specifically, the study sought to identify whether alternative anthropometric measures showed greater magnitudes of change than traditional anthropometric measures. The following alternative (experimental) hypotheses were formulated:

H₃) Alternative anthropometric measures and traditional anthropometric measures will change significantly over a year.

H₄) Alternative anthropometric measures will show greater magnitude of change over a year than traditional anthropometric measures.

4.3.2 Methods

4.3.2.1 Study design and participants

Participants already involved in Part A of Study One continued to partake in monthly assessments to meet the requirements of Part B. Therefore no further recruitment and preliminary assessment was required. Please refer to Chapter 4.2.3.1 for details regarding recruitment processes, inclusion and exclusion criteria and preliminary screening methods.

4.3.3. Procedure

The same procedure as detailed in Chapter 4.2.4 was followed, with measurements being collected over the extended time period of a year. The mean time between measurement sessions is shown in Table 4.4.

Table 4.4. Mean (\pm SD) time (days) between measurement sessions over the 12 month testing period.

Month	Mean \pm SD time (days) between months
Baseline – 2	33.8 \pm 6.0
2 – 3	31.9 \pm 5.6
3 – 4	33.9 \pm 6.0
4 – 5	33.5 \pm 6.1
5 – 6	31.7 \pm 6.0
6 – 7	32.2 \pm 7.4
7 – 8	29.5 \pm 6.9
8 – 9	31.6 \pm 8.8
9 – 10	30.9 \pm 7.1
10 – 11	33.0 \pm 8.6
11 – 12	33.9 \pm 6.9
Baseline – 12	354.4 \pm 25.2

4.3.4 Data analysis considerations for the measurement of change

4.3.4.1 Growth and change

“Growth and change are normal features of biological, psychological and sociological phenomena” (Stull, 2008). The analysis of change is a fundamental component of many research endeavours in almost every discipline (Fitzmaurice & Molenberghs, 2008), enabling the documentation of an individuals’ progress. Despite its obvious substantive importance, there has been much controversy over the years about the measurement of change (Willett, 1994) and in the measurement of change the reliability of the difference score has been one of the most discussed, yet least understood topics.

A general misconception in the measurement of change is that individual change should be viewed as an increment, as the difference between ‘before’ and ‘after’ (Willett, 1994). Traditionally, individual change has been measured by the collection of data at two points in time and the computation

of a difference score, a residual change score, a regression estimate of true change, or some other two-wave measure of growth (Willelt, 1989). Difference scores, the subtraction of one score from another to create a measure of a distinct construct (Peter et al., 1993), have been criticised as they purport a negative correlation with initial status (Willelt, 1994). Residual change scores intend to describe the true change that each person would have experienced, if everyone had 'started out equal' or had the same 'initial status' (Willet, 1994), thus overcoming this issue (Willet, 1989). However, current status is a product of prior change, and current change determines future status. Thus "a correlation between change and status is an almost inevitable fact of life" (Willelt, 1995).

Despite the issues discussed above many studies do lend themselves to the measurement of change (Singer & Willelt, 2003), however as with any study in order to adequately address the research hypotheses the most appropriate and powerful analysis technique should be employed. Willelt (1994) suggests there are three requisite methodological features of any study of change. The availability of (1) multiple waves of data; (2) a substantively meaningful metric for time; and (3) an outcome that changes systematically.

4.3.4.2 Multiple waves of data

Conceptualising change as an increment accrued between the beginning and the end of a particular period of growth can ignore the potentially interesting features of change that occur continuously throughout the duration of an investigation (Miller et al., 2007; Willelt, 1998). For example, Figure 4.10 depicts three hypothetical weight losses from month one to month 6 and Figure 4.11 depicts the same hypothetical weight losses measured at monthly intervals over the same time period. If viewing change as the increment accrued between month one and six, it would be concluded that all individuals showed no change over this time period. This would be true for example X, however this would ignore the patterns of change of

examples Y and Z (Fig. 4.11). Thus two-wave (before and after) studies are insufficient for studying change (Willet, 1994) as they ignore potentially interesting changes that may occur in between these two waves of data.

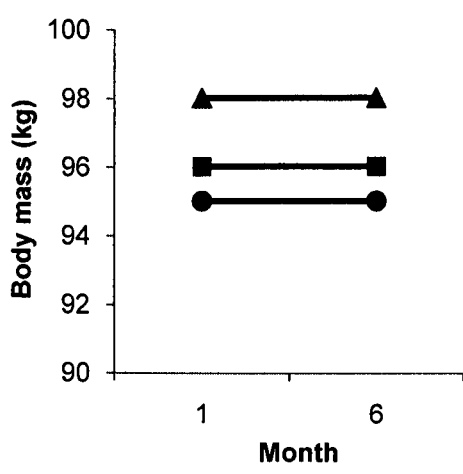


Figure 4.10. Hypothetical weight loss (kg) over 6 months measured pre and post 6 months.

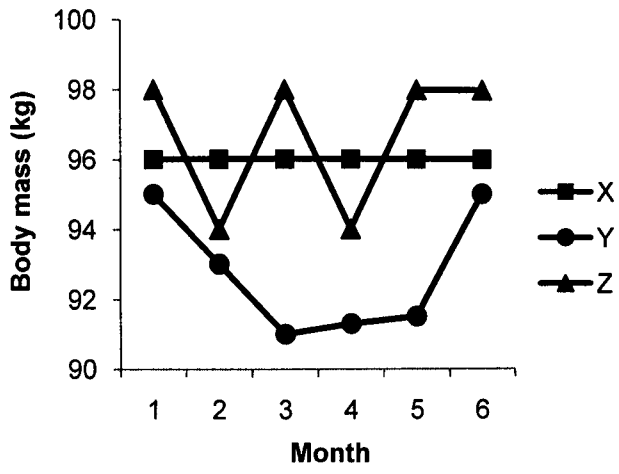


Figure 4.11. Hypothetical weight loss (kg) over 6 months measured at monthly intervals over 6 months.

This issue can be overcome by the collection of more than two waves of data (Willet, 1997). Repeated measurements over extended periods of time allow the continuous process of change to be easily and efficiently documented (Willet, 1995), permitting analysis of change patterns over time. For example, for the hypothetical weight loss patterns shown in Figure 4.11, including six waves of data, it could be concluded that although pattern Z indicates no change from month 1 to month 6, a continual decrease in body weight occurred for the first 3 months, where after weight was maintained until month 5, before increasing to initial starting weight. Without these additional waves of data this pattern of change would be undetected.

In order to adequately represent change patterns it is important to choose the appropriate number of waves. If the attribute of interest is changing steadily and smoothly over a long period of time, perhaps three or four widely spaced measurements on each person will be sufficient to capture the shape and direction of change. But many more closely spaced measurements may

be required for more complex patterns of change (Willett, 1994). The collection of more waves of data leads to greater reliability and precision for the measurement of change (Donnellan & Conger, 2007) and in general, more waves are always better, within cost and logistical constraints (Singer & Willett, 2003). Ideally, theory should guide the rational choice of the frequency of measuring change so that subsequent analyses have meaningful substantive interpretations (Willett, 1997).

4.3.4.3 Time metric

Time is the fundamental predictor in every study of change; it must be measured reliably and validly in a sensible metric (Singer & Willett, 2003). Choice of a time metric affects several interrelated decisions about the number and spacing of data collection waves. Each of these, in turn, involves consideration of costs, substantive needs, and statistical benefits (Singer & Willett, 2003). Often the decision of when to assess participants is based on practical considerations rather than deriving from theoretical or conceptual concern which can be deleterious. There is no single answer about the most sensible metric for time, simply one that reflects the time you expect to be most useful for your outcome should be chosen. In light of the weight loss and weight re-gain patterns depicted in Figures 4.7 - 4.9, and research evidence that suggests frequent monitoring of weight loss can help maintain weight loss and can be used as a long-term technique for managing weight, (Boutelle & Kirschenbaum, 1998; Butryn et al., 2007; Klem et al., 1997; McGuire et al., 1999; O'Neill & Brown, 2005) the present study aimed to collect 12 waves of data at monthly intervals.

4.3.4.4 Systematic change

Individual growth models are designed for continuous outcomes whose values change systematically over time (Singer & Willet, 2003). An issue fundamental to the measurement of growth and change is whether the selected measure remains construct valid across subsequent occasions of

measurement, and whether the scores obtained are equitable from occasion to occasion (Willeit, 1989). Reliability can be defined as the consistence of measurements, or of an individual's performance on a test; or the 'absence of measurement error' (Atkinson & Nevill, 1997). Although the reliability of change measurement depends directly on outcome reliability, the precision with which estimates of individual change are made depend more on the number and spacing of the waves of data collection. The efforts made in the present study to control measurement reliability and precision (Chapter 3.6), and choosing a suitable number of waves of data collection at appropriate time intervals, should offset the deleterious effects of measurement error in the outcome variables (Singer & Willett, 2003).

4.3.5 Data analysis considerations for the measurement of change in Study One, Part B

The aim of the Study One, Part B, is to examine change in traditional and alternative anthropometric measures over an extended time period of a year, and compare their magnitudes of change, in order to identify whether some discern greater change than others. However, due to the differing units of measurement of these anthropometric variables, comparison using absolute change is inappropriate. Historically, the primary variable of interest in measuring weight loss program intervention success has been pounds lost during the program (Sargent et al., 2000). However, this measure, the classic standard of success, does not account for individual variability (Atkinson, 1993).

Reporting a percentage change provides immediately accessible data in relevant terms, which is why researchers commonly report this statistic (Vickers, 2001). Indeed in obesity research the concept of utilising percent change as an outcome variable is widely accepted with much research focusing on percent weight change or percent BMI change (Table 4.5).

Table 4.5. Studies utilising percent weight change and percent BMI as main outcome variables.

Author	Focus	Method	Variables measured
Berkowitz et al. (2003)	Sibutramine in adolescent obesity	n=82 randomised to behaviour therapy and sibutramine group or behaviour therapy and placebo group for first 6 months, all received follow-up treatment months 7-12	Main outcome measure percent change in BMI
Bray et al. (1999)	Sibutramine and weight loss	n=1047 randomised to 24 weeks of treatment with one of six doses of sibutramine	Mean percent weight loss from baseline
Bray et al. (2003)	Safety of topiramate (TPM) for weight loss	n=385, randomised to receive placebo or TPM over 24 weeks	Mean percent weight loss from baseline to 24 weeks
Busetto et al. (2004)	Short-term effects of weight loss on CV risk factors	n=650, five metabolic risk factors measured before and 15.3±2.1 months after laparoscopic gastric banding	Relationship between mean percent change and change in CV risk factors
Chaston & Dixon (2008)	Systematic review of change in visceral versus subcutaneous abdominal fat	Medline and Embase searched for imaging-based measurements of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) before and after weight loss interventions.	Percent weight loss, percent change in VAT and SAT
Ensrud et al. (2003)	Weight loss and bone mass	n=9704 females, 65y+, completed baseline measures for prospective study of osteoporotic fractures (1986-1988). N=6785 returned for 4 th examination (1992-1994).	Percent weight loss from baseline to 4 th examination, loss/maintenance/gain defined using % cut-offs
Epstein et al. (1995)	Weight change in obese children	n=61, treatment group targeted increasing activity or decreasing sedentary behaviour	Mean percent weight change and mean percent body fat change
Finer et al. (2000)	Orlistat and obesity	n=288, prescribed low-energy diet and assigned to placebo group or orlistat group for 1 year	Primary parameter percent weight change
Freemark & Bursey (2001)	Metformin, BMI and glucose tolerance	n=29 randomised to receive metformin or placebo for 6 months	Mean percent change in BMI
Hirose et al. (2002)	Pioglitazone effect on metabolic parameters and body fat distribution	Participants with type II diabetes (n=10) studied before and after 3 month treatment of pioglitazone	Mean \pm SD of BMI and metabolic parameters at baseline and month 3, plus percent change over 3 months
Sampalis et al. (2004)	Impact of weight-reduction surgery on health related costs	Comparison of health costs of treatment group (surgery) and control group (no surgery) followed for maximum of 5 years	Primary outcome overall direct healthcare costs and reporting of percent change in weight and BMI
Swinburn et al. (1991)	Insulin resistance and weight gain	n=192, glucose disposal rates measured and weight change followed over 3.5±1.8 y.	Mean percent weight change per year
Wallace et al. (1995)	Involuntary weight loss in older outpatients	n=247, weight, height, skinfolds, circumferences, health status measures and blood measures obtained at baseline and followed annually for two years	Mean annual percent weight change. Absolute change for skinfolds and circumferences.
Thai & Wadden (2005)	Review of major commercial weight loss programs	Review of websites and Medline search including only randomised trials at least 12 weeks in duration	Mean percent weight loss

However, it is acknowledged that this method is not without limitation. Vickers (2001) reported that when constructing regression models, the highest statistical power was obtained by using post-treatment scores by baseline score. When compared to the use of absolute differences or percentage change from baseline, post-treatment scores by baseline score still resulted in higher statistical power.

The variables in study one differ not only in their units of measurement, but also in their capacity for change. Table 4.6 shows examples of the percentage changes that could occur if transferring from a high risk category to a low risk category. This highlights that the variables are non-comparable when using percentage change due to their differing variances. Even with the potential of defining a theoretical range for each variable and then dividing the percentage change by its theoretical range the use of percentage change in the current study was deemed unacceptable.

Table 4.6. Risk categories for select anthropometric variables and their capacity for change (for females)

Risk Category	WHR ¹	BF(%) ²	BMI (kg.m ⁻²) ³
Low Risk	≤0.80	23-35	25-27
Moderate Risk	0.81 – 0.89	35-40	27-32
High Risk	>0.89	>40	32-34
Percentage change when transferring from low risk to high risk category*	11.3%	73.9%	20%

*Calculations based on maximum low risk score and minimum high risk score
¹Welborn et al., 2003; ²Gallagher et al., 2000; ³Whitney & Rolfes, 2005

Another technique considered to overcome the aforementioned issues was that of the Phantom Stratagem; a method used to convert raw data of different anthropometric variables to one common raw value (Ferreira et al., 2004; Gaines, 2001). Phantom stratagem is essentially based on the concept of a theoretical reference human, which is named as phantom (Singh & Singh, 2007). It is an arbitrary unisex reference human with specified

anthropometric characteristics such as height, mass, percent body fat, fat and muscle mass, girths, skinfold thicknesses and breadths (Norton & Olds, 1996). The primary use of the Phantom model is to scale anthropometric variables to a standard height (170.18cm) or size, using the equation:

$$Z = \frac{V_{adj}-p}{s}$$

Where p is the phantom mean value, s is the phantom standard deviation, and V_{adj} is the true adjusted measurement (Singh & Singh, 2007).

It was assumed that in the population of Phantom models each of these characteristics was normally distributed about the Phantom value (p) with a standard deviation (s). Reported male and female coefficients of variation were used to calculate the s values (Ross & Marfell-Jones, 1991). The authors of the technique maintain that because data have been scaled to a common standard, and expressed as ratios to the corresponding standard deviations, different anthropometric variables can be compared both between and within samples (Shephard, 1991). The Phantom strategy has since been applied to longitudinal and cross-sectional growth studies and comparative studies of athletes (Norton & Olds, 1996), allowing quantification of differences between individuals or within an individual in terms of differences in z-scores. Positive z values indicate that a particular variable is larger than the phantom reference model and negative values indicate that it is smaller (Shephard, 1991).

Ross and Wilson based the Phantom's anthropometric characteristics on large population surveys. Girths were taken from data of Wilmore and Behnke (1969, 1970), skinfolds thicknesses from unpublished data of Yuhasz (Norton & Olds, 1996) and other measures from Garrett and Kennedy (1971) (Ross & Marfell-Jones, 1991). A list of the Phantom means and standard deviations included within an ISAK Level I restricted profile can be found in Table 4.7.

Table 4.7. Phantom means and standard deviations

		Mean (p)	SD (s)
BASIC	Stature (cm)	170.18	6.29
	Mass (kg)	64.58	8.60
SKINFOLDS (mm)	Triceps	15.4	4.47
	Subscapular	17.2	5.07
	Biceps	8	2.00
	Iliac Crest	22.4	6.80
	Supraspinale	15.4	4.47
	Abdominal	25.4	7.78
	Front thigh	27	8.33
	Medial Calf	16	4.67
GIRTHS (cm)	Arm relaxed	26.89	2.33
	Arm (flexed & tensed)	29.41	2.37
	Waist (min)	71.91	4.45
	Waist (umbillical)	79.06	6.95
	Hips	94.67	5.58
	Calf	35.25	2.30
BREADTHS (cm)	Humerus	6.48	0.35
	Femur	9.52	0.48

(Ross & Marfell-Jones, 1991).

It is important to note that Ross and his colleagues used a relatively small heterogeneous convenience sample to create their reference phantom (Shephard, 1991), thus limiting its applicability to the wider population. The phantom is also a calculation scaling device rather than a normative system (Nevill et al., 2006). It is a hypothetical, unisex reference human with defined p values for many anthropometric measures, which each were ascribed a standard deviation in an assumed, symmetrical, unimodal distribution (Ross & Marfell-Jones, 1991). Consequently, the interpretation of Z score of the Phantom model like a percentile, cannot be a complete interpretation, but only a first approach that will have later to be clarified based on characteristics like: sex, age, diet, physical activity or ethnic group of the subject of study (Romy, 2006). Furthermore, reference data are only

available for the individual skinfold, girth and breadth measures detailed in Table 4.7, with standard deviation scores calculated using male and female coefficients of variation (Ross & Marfell-Jones, 1991). Whilst mean scores could be used to calculate somatotype ratings, $\Sigma 8SF$ and %BF, no standard deviation measures would be available, thus making z scores unattainable. Therefore, this data handling method was also discarded. However, the use of Z-scores as a scaling system was considered further. The Z scale converts raw scores to units of standard deviation in which the mean is zero and a standard deviation is 1.0 (Thomas & Nelson, 2001). The Z-score can be defined as the difference between the value for an individual and the median value of the reference populations for the same age or height, divided by the standard deviation of the reference population. This can be written in equation form as:

$$Z - \text{score} = \frac{(\text{observed value}) - (\text{mean reference value})}{\text{standard deviation of reference population}}$$

Z-scores are commonly used because they offer two major advantages; allowing identification of a fixed point in the distribution of different indices, and the calculation of summary statistics (WHO: Physical Status, 2005). They are also particularly useful when amalgamating scores on different scales (Diamond & Julie, 2001). As the anthropometric variables in the current study differ in their units of measurement and in their scales of measurement, direct comparison between them is difficult. However, converting these anthropometric measures into Z-scores permits comparison because all distributions of Z-scores have the same mean and the same standard deviation (Graveter & Wallnau, 2009), therefore one variable can be compared to another with respect to their positions in distributions. Neither the shape of the distribution of a particular variable, nor its correlation with another variable is affected by transforming it to a Z-score (Cohen et al., 2003). Additionally it does not change an individual's position in the distribution (Graveter & Wallnau, 2009).

4.3.6 Data handling and statistical analysis for Study One, Part B

In order to examine change in traditional and alternative anthropometric measures over a year, and answer H_3 , the same statistical procedures utilised in Study One, Part A were used. In order to compare magnitudes of change in anthropometric variables, baseline data was converted to Z-scores, allowing identification of how many standard deviations away from the mean each individual's score was for each anthropometric variable. All further anthropometric scores at each time point were converted to Z-scores using the baseline population mean and standard deviation. The Z-scores, representing each individuals change from the baseline population mean are unit free. A multivariate ANOVA with Bonferonni adjustment for multiple comparisons was then used to answer H_4 .

Mauchly's test again indicated that the assumption of sphericity had been violated. Therefore when examining change using Wilk's Lambda Repeated Measures Manova, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. When examining residual plots, no variables appeared to be influencing or were being influenced by other variables.

4.3.7 Results

Data are presented for all participants who completed all 12 anthropometric measurement sessions ($n=60$). Baseline demographic, traditional and alternative anthropometric measures are provided in Table 4.8. Participant drop out and retention rates are provided in Table 4.9. All data are presented in raw form (Chapter 4.3.7.1) or Z-score form (Chapter 4.3.7.2) with an alpha level set at 0.05.

Table 4.8. Mean (\pm SD) baseline demographic and anthropometric measures for all participants involved in Part B of Study One (n=60), including breakdown by gender and BMI classification*.

	Male (n=10)	Female (n=50)	Overweight (n=23)	Obese (n=21)	Morbidly Obese (n=16)	All (n=60)
Age (years)	58.5 \pm 16.5	52.2 \pm 14.9	55.4 \pm 14.7	52.5 \pm 17.2	52.8 \pm 14.3	55.6 \pm 5.8
Height (cm)	174.1 \pm 6.1	162.7 \pm 6.1	167.7 \pm 6.8	162 \pm 6.8	164.7 \pm 8.3	165.4 \pm 7.2
Mass (kg)	96.2 \pm 17.6	85.9 \pm 15.2	77.2 \pm 1.5	84.4 \pm 8.5	107.0 \pm 15.9	87.3 \pm 15.1
BMI (kg.m⁻²)	31.7 \pm 5.1	32.5 \pm 5.5	27.4 \pm 1.5	32.2 \pm 1.2	37.3 \pm 2.3	32.0 \pm 5.0
WHR	1.0 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	1.0 \pm 0.1	0.9 \pm 0.1
BF (%)	24.5 \pm 5.7	36.3 \pm 3.8	30.0 \pm 6.4	35.8 \pm 3.2	38.7 \pm 4.1	34.3 \pm 6.0
Σ8SF (mm)	133.5 \pm 52.6	209.6 \pm 43.1	155.4 \pm 42.9	204.3 \pm 34.1	247.0 \pm 36.1	196.9 \pm 52.8
Endomorphy	4.7 \pm 1.6	6.8 \pm 1.2	5.2 \pm 1.4	6.8 \pm 0.8	7.8 \pm 0.8	6.5 \pm 1.5
Mesomorphy	6.5 \pm 1.7	7.1 \pm 1.5	5.6 \pm 0.9	7.3 \pm 0.8	8.6 \pm 1.4	7.0 \pm 1.6
Ectomorphy	0.5 \pm 0.5	0.3 \pm 0.3	0.7 \pm 0.4	0.1 \pm 0.0	0.1 \pm 0.0	0.3 \pm 0.4

*as defined in Table 2.1

Table 4.9. Number of participants at each time point, grouped by gender and BMI classification*, and retention rates over the testing period (%).

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Male	17	17	17	17	12	12	12	11	11	11	11	11
Female	73	73	73	73	65	62	56	52	50	50	49	49
Overweight	27	27	27	27	25	25	24	24	23	23	23	23
Obese	34	34	34	34	31	29	25	22	21	21	21	21
Morbidly Obese	29	29	29	29	21	20	19	17	17	17	16	16
Total	90	90	90	90	77	74	68	63	61	61	60	60
Retention (%)**	-	100	100	100	86	82	76	70	68	67	66	66

*as defined in Table 2.1

**calculated from month one (n=90)

4.3.7.1 Change in anthropometric measures

Figure 4.12 shows that similar proportions of the participants were classified as mesomorph-endomorphs at baseline and month 12 (32% and 27%, respectively). The number of participants classified as endomorphic mesomorphs between baseline and month 12 increased from 43% at baseline, to 67% at month 12. A decrease was observed in the number of participants classified as mesomorphic endomorphs (25% to 6%). Figure 4.13 illustrates the pattern of change over the year testing period.

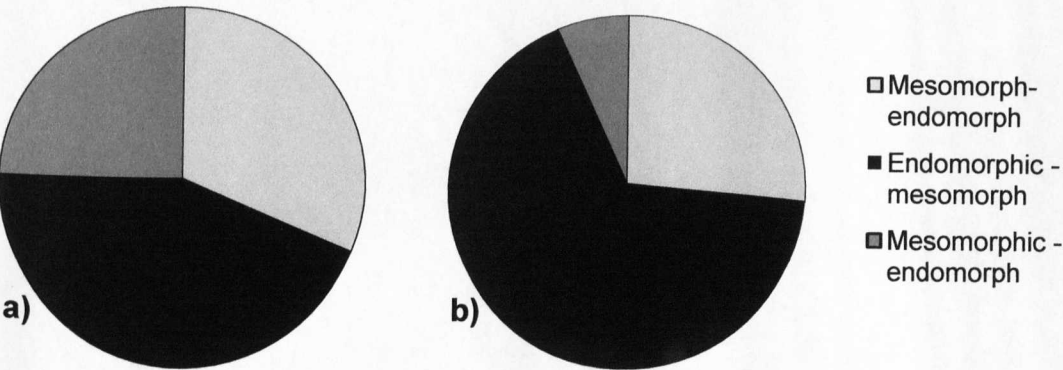


Figure 4.12. Somatotype distribution of participants (n=60) at baseline (a) and month 12 (b).

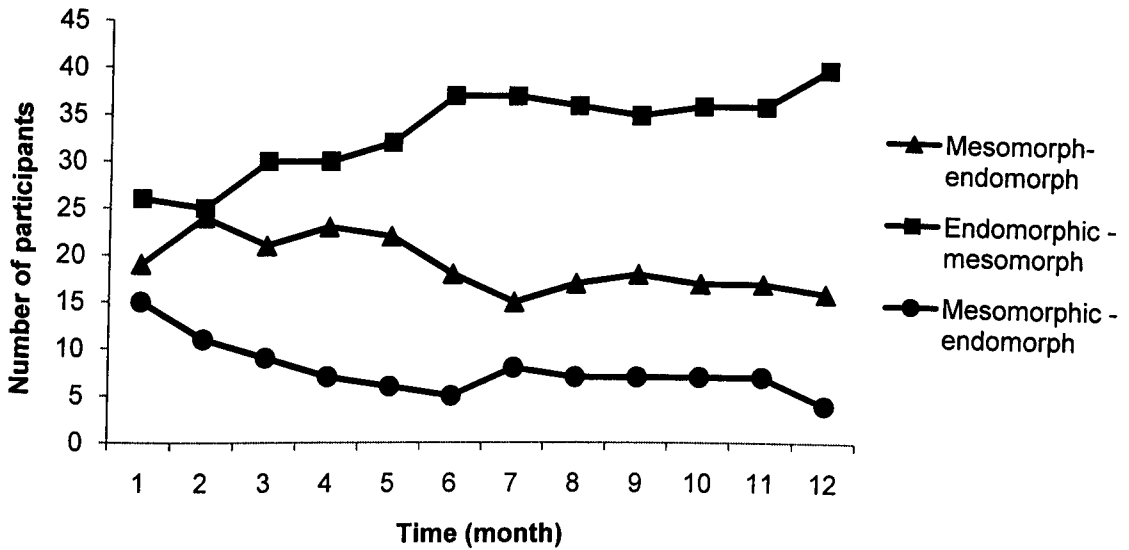


Figure 4.13. Somatotype distribution of participants (n=60) from baseline to month 12.

Due to the small changes in global somatotype only the mean somatotype at baseline, and months 4, 8 and 12 are plotted on the somatochart (Fig. 4.14) to aid visualisation. The differences among the scatter of somatotypes about their means (SAMs) did not differ, with a narrow range of 1.8-1.9 ($F=0.89_{11,57}, P>0.05, \text{Eta}^2=0.015, 1-\beta=0.506$). When the whole somatotype means were compared significant differences were observed ($F=207.393_{11,57}, P<0.05, \text{Eta}^2=0.779, 1-\beta=1.00$). No significant changes were observed between months (SAD), however from baseline to month 12 a significant change was observed ($\text{MD}=2.2\pm0.2, P<0.05$).

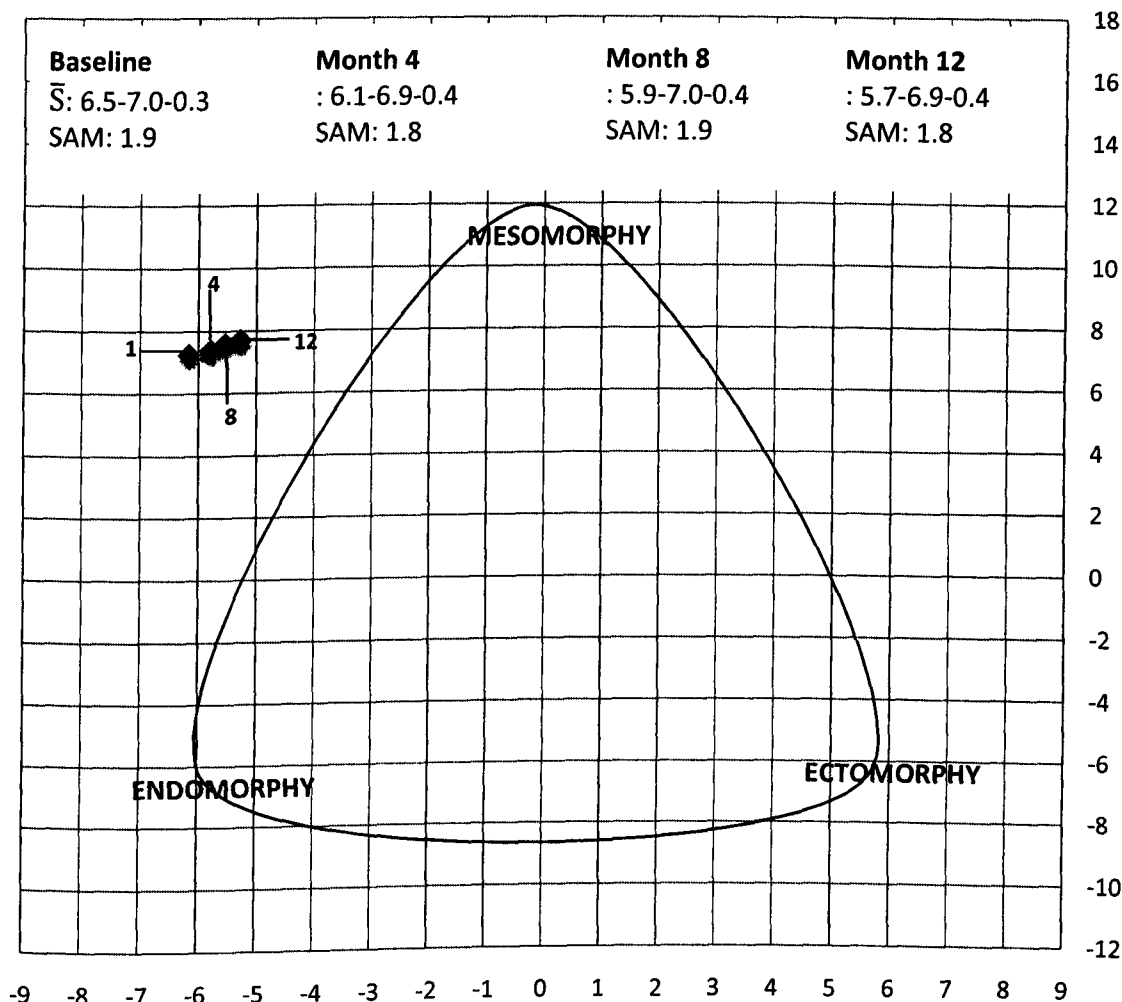


Figure 4.14. Mean somatotype (n=60) at baseline and months 4, 8 and 12

* \bar{S} =mean somatotype, SAM=somatotype attitudinal mean,

Figures 4.15 and 4.16 illustrate the mean change between baseline and month 12 for alternative and traditional anthropometric measures, respectively. All somatotype components showed significant change (endomorph; $F=35.408$, $P<0.05$, $Eta^2=0.37$, $1-\beta=1.00$, mesomorph; $F=1.190$, $P<0.05$, $Eta^2=0.31$, $1-\beta=0.656$; and ectomorph; $F=5.520$, $P<0.05$, $Eta^2=0.10$, $1-\beta=0.951$). $\Sigma 8SF$ also showed significant change, decreasing by $34\pm 4mm$ ($F=33.632$, $P<0.05$, $Eta^2=0.37$, $1-\beta=1.00$).

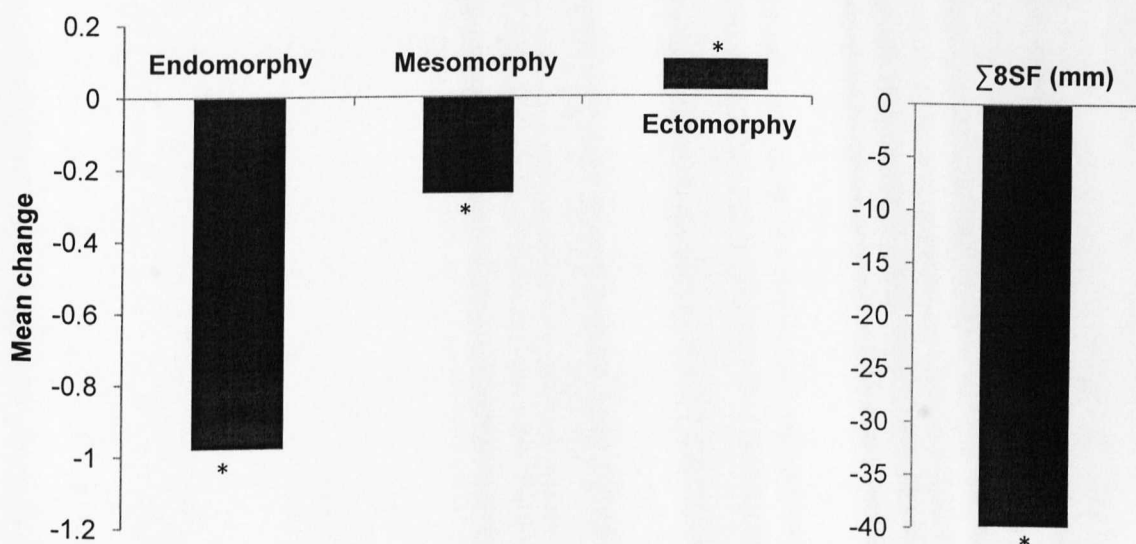


Figure 4.15. Mean change in alternative anthropometric measures from baseline to month 12 (n=60).

*P<0.05

Vertical bars show standard errors of the mean

BMI, mass and %BF decreased significantly from baseline to month 12 ($F=9.878$, $P<0.05$, $Eta^2=0.24$, $1-\beta=0.98$; $F=9.403$, $P<0.05$, $Eta^2=0.26$, $1-\beta=0.974$; $F=26.123$, $P<0.05$, $Eta^2=0.31$, $1-\beta=1.00$, respectively). WHR was the only anthropometric variable not to show significant change over the year ($F=3.537$, $P>0.05$, $Eta^2=0.06$, $1-\beta=0.820$).

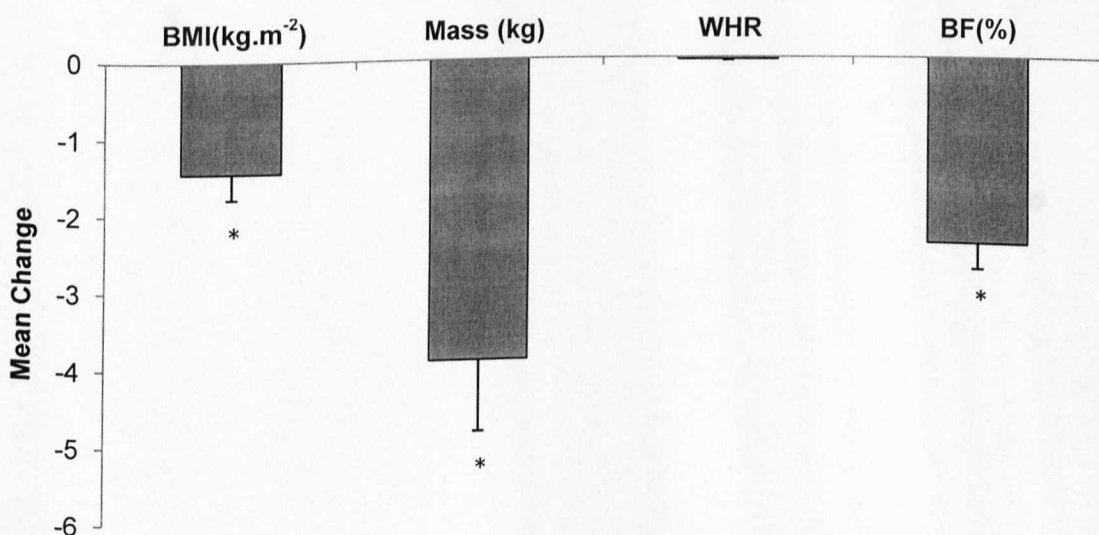


Figure 4.16. Mean change in traditional anthropometric measures from baseline to month 12 (n=60)

*P<0.05

Vertical bars show standard errors of the mean

The only anthropometric variables that showed significant change between months were BMI, mass, %BF, Σ 8SF and endomorphy between months one and two (mean difference $-0.4\pm0.1\text{kg.m}^{-2}$, $P<0.05$; $-1.0\pm0.2\text{kg}$, $P<0.05$; $-0.4\pm0.1\%$, $P<0.05$; $5.9\pm1.5\text{mm}$, $P<0.05$ and -0.2 ± 0.03 , $P<0.05$, respectively), and Σ 8SF, endomorphy and %BF between months 2 and 3 (mean difference $-5.7\pm1.1\text{mm}$, $P<0.05$; -0.1 ± 0.03 , $P<0.05$, $-0.4\pm0.1\%$).

The results in Table 4.10 separate the change in anthropometric variables over three discrete time periods and indicate that %BF, Σ 8SF and endomorphy were the only anthropometric variables that showed significant change over each time period. BMI, WHR, and mesomorphy failed to show significant change at any of the time periods, and mass showed significant change between months 4 and 8. Analysis of global somatotype means between these time periods identified significant change from baseline to month 4, months 4 to 8, and months 8 to 12 (Table 4.10). The mean somatoplots in Figure 4.14 reflect this difference, as they move from left to right across the somatochart.

Table 4.10. Mean change between months in traditional and alternative anthropometric variables (n=60).

	Δ Baseline month 4	Δ Month 4 – 8	Δ Month 8 –12	Δ Baseline – month 12
TRADITIONAL				
BMI (kg.m^{-2})	-0.6 ± 0.2	-0.3 ± 0.2	-0.5 ± 0.2	$-1.4\pm0.3^*$
Mass (kg)	-1.7 ± 0.5	$-0.9\pm0.5^*$	-1.3 ± 0.4	$-3.9\pm0.9^*$
WHR	-0.01 ± 0.01	-0.01 ± 0.00	-0.01 ± 0.00	-0.03 ± 0.01
BF (%)	$-1.0\pm0.2^*$	$-0.7\pm0.2^*$	$-0.7\pm0.2^*$	$-2.4\pm0.3^*$
ALTERNATIVE				
Σ 8SF (mm)	$-15.7\pm2.6^*$	$-7.9\pm2.1^*$	$-10.1\pm1.9^*$	$-33.7\pm4.14^*$
Endomorphy	$-0.3\pm0.1^*$	$-0.2\pm0.1^*$	$-0.2\pm0.1^*$	$-0.8\pm0.1^*$
Mesomorphy	-0.01 ± 0.04	-0.01 ± 0.03	-0.03 ± 0.03	$-0.10\pm0.07^*$
Ectomorphy	0.05 ± 0.02	0.03 ± 0.02	0.04 ± 0.02	$0.12\pm0.03^*$
MD	0.7^*	0.7^*	0.8^*	2.2^*

* $P<0.05$

Values rounded to two decimal places

In summary, all traditional and alternative anthropometric variables showed significant change from baseline to month 12, with the exception of WHR (Fig.4.15-4.16). Additionally global somatotype, endomorphy $\Sigma 8SF$ and %BF significantly decreased at all interim periods (Table 4.10). Thus H_3 , that alternative and traditional anthropometric measures would show significant change over a year, is accepted for all alternative anthropometric variables and all traditional anthropometric variables excluding WHR.

4.3.7.2 Comparison of magnitude of change

Due to the small variation in ectomorphy values among participants, particularly in those classified as morbidly obese, it was not possible to standardise the magnitude of change using the procedures described in Chapter 4.3.6. As identified by Carter & Heath (2005) focusing on endomorphy and mesomorphy components are more practical. Furthermore, as the analysis of global somatotype change already involves specialised procedures to calculate the 3-dimensional distance between two somatopoints, again applying further transformation procedures was deemed inappropriate. Thus the following section will compare the magnitude of change between traditional anthropometric measures and the following alternative anthropometric measures only; $\Sigma 8SF$, endomorphy and mesomorphy.

When comparing magnitudes of change from baseline to month 12 significant differences were apparent ($F=7.027$, $P<0.05$, $Eta^2=0.99$, $1-\beta=1.00$). Figure 4.17 illustrates the magnitude of change (Z-scores) in alternative anthropometric measures in comparison to traditional anthropometric measures. $\Sigma 8SF$ showed a significant decrease of -1.1 ± 0.1 Z-score over the year testing period. This was significantly greater than the decrease observed in mass (-0.42 ± 0.2 Z-scores) and WHR (-0.32 ± 0.2 Z-scores). However, this was not significantly greater than the changes observed in BMI and %BF.

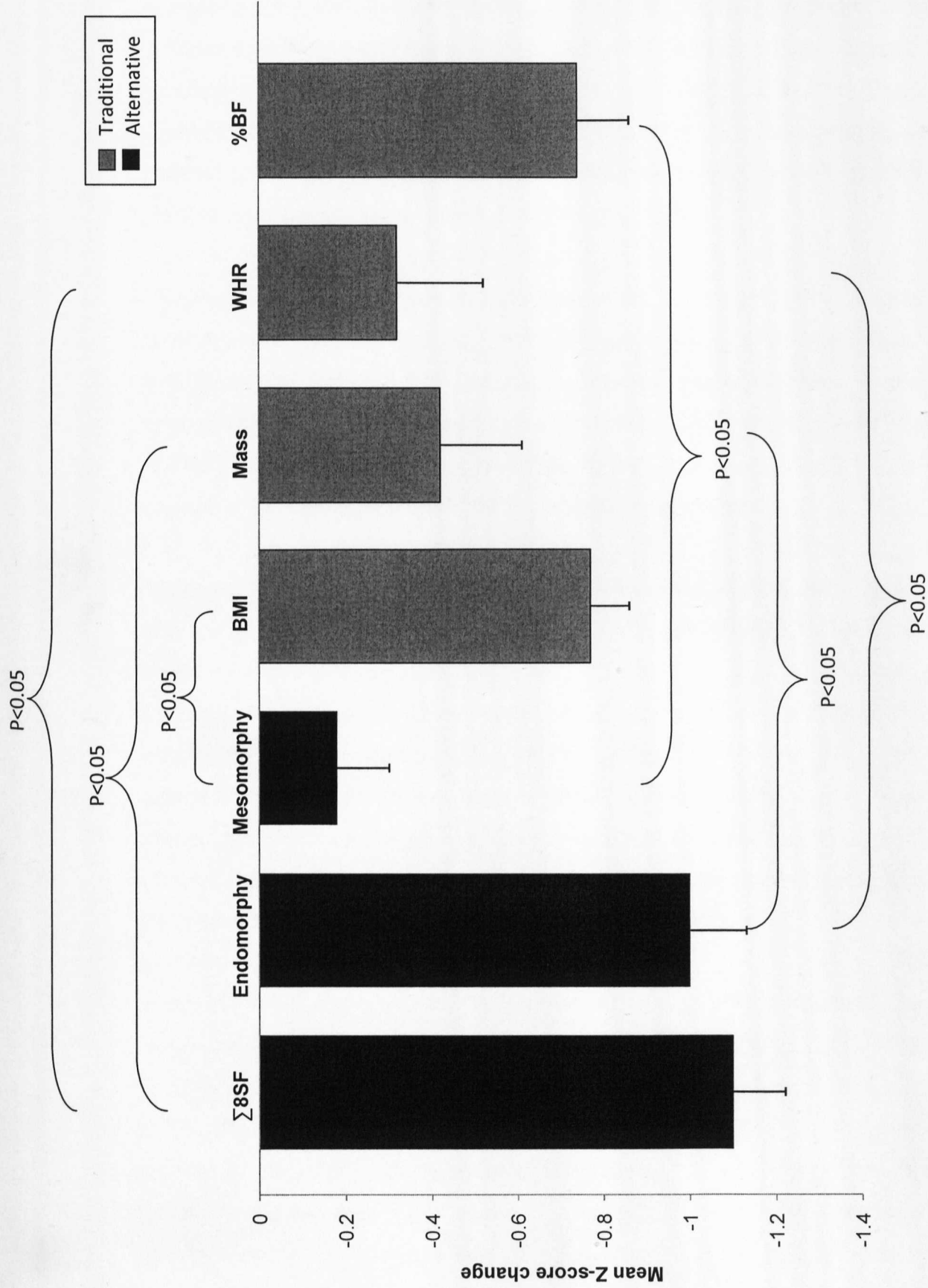


Figure 4.17. Comparison of magnitude of change between traditional and alternative anthropometric measures from baseline to month 12 (n=60). Vertical bars show standard errors of the mean.

The same pattern was observed when comparing the magnitude of change in endomorphy over the year testing period, with the magnitudes of change in traditional anthropometric measures (Fig. 4.17). Endomorphy showed the greatest magnitude of change, decreasing by -1.0 ± 0.1 Z-scores. This was significantly greater than the decrease observed in mass (-0.42 ± 0.2 Z-scores) and WHR (-0.32 ± 0.2 Z-scores). This was not however significantly greater than the changes observed in BMI and %BF.

Significant differences were apparent between the magnitude of change in mesomorphy and BMI and %BF, with significantly larger changes observed in BMI and %BF (Fig. 4.17). BMI showed a decrease of -0.77 ± 0.1 Z scores, almost 4 times the change seen in mesomorphy. %BF showed a decrease of -0.74 ± 0.1 Z scores, again significantly larger than the -0.18 ± 0.1 Z score change observed in mesomorphy from baseline to month 12.

Although BMI, mass, %BF, $\sum 8SF$ and endomorphy showed significant change between months one and two, the magnitudes of change between these measures were not significantly different. BMI, %BF, $\sum 8SF$ and endomorphy did show significantly larger magnitudes than WHR (mean difference, -0.26 , $P < 0.05$; -0.16 , $P < 0.05$; -0.14 , $P < 0.05$; and -0.21 , $P < 0.05$, respectively), however the change in WHR between months 2 and 3 was not statistically significant. $\sum 8SF$, endomorphy and %BF also showed significant change between months 2 and 3, however again the magnitude of change between these measures was not significantly different.

From baseline to month 4 the magnitudes of change in anthropometric measures were significantly different ($F = 2.992$, $P < 0.05$, $Eta^2 = 0.04$, $1 - \beta = 0.90$). Significant differences were also apparent from months 4 to 8, and 8 to 12 ($F = 2.623$, $P < 0.05$, $Eta^2 = 0.04$, $1 - \beta = 0.86$ and $F = 2.627$, $P < 0.05$, $Eta^2 = 0.04$, $1 - \beta = 0.86$). Comparison of magnitudes of change from baseline to month 4 showed that $\sum 8SF$ showed the greatest magnitude of change (Z-scores) showing a decrease of -0.5 ± 0.1 Z-scores. Whilst this was significantly greater than the change observed in mesomorphy, mesomorphy

did not show significant change from baseline to month 4. There was no significant difference in the magnitude of change observed between traditional and alternative anthropometric measures. The same patterns of change were observed between months 4 to 8, and 8 to 12, with no significant difference between the magnitudes of change in any of the traditional or alternative measures.

To summarise, $\Sigma 8SF$ and endomorphy both showed significantly greater magnitudes of change than mass and WHR from baseline to month 12, however comparable magnitudes of change with BMI and %BF (Fig.4.17). Mesomorphy did not show significantly greater magnitude of change compared to any traditional measure from baseline to month 12. In fact it showed significantly smaller magnitude of change than BMI and %BF. There was no significant difference in the magnitudes of change between traditional and alternative anthropometric between any of the interim periods. Therefore H_4 , that alternative measures would show greater magnitudes of change than traditional measures over a year, is accepted for $\Sigma 8SF$ and endomorphy compared to mass and WHR only.

4.3.8 Discussion

4.3.8.1 Change in anthropometric measures over time

At baseline, all participants in the current study were classified as extreme mesomorphic-endomorphs, mesomorph-endomorphs and endomorphic-mesomorphs (Fig.4.12). Few studies have examined somatotype in obese populations however the above results are similar to those of Koleva et al. (2000), who examined somatotype characteristics in an obese population. Of 194 individuals classified as obese, all fell in to three somatotype categories observed in the present study. The analysis of whole somatotype change, identified that participants that were classified as mesomorph-endomorphs changed their categorisation to endomorphic-mesomorphs from baseline to month 12 (Fig.4.12), suggesting a reduction in the fat component. This was

verified by the significant reduction observed in the endomorphy component (Fig. 4.15) observed from baseline to month 12 and by the movement of the mean somatopoints plotted in Figure.4.14 from left to right. This highlights a benefit of the use of somatotype, in that it can show a 'type' alteration in the physique, not only in the quantification and proportion of fat and fat-free mass (Fett et al., 2006).

The results reported in the present study indicate that all traditional and alternative anthropometric variables showed significant change over the year testing period, with the exception of WHR (Fig. 4.15 and 4.16), thus H_3 is accepted. The use of WHR to assess changes in fat distribution is questionable (Van der Kooy et al., 1993) with some studies failing to show change in WHR with weight loss (Gardner et al., 2007; Ross et al., 1991; Slentz et al., 2004; Zamboni et al., 1993). Those that have found significant change in WHR have reported relatively small changes and the change has not been predictive of change in visceral fat (Van der Kooy et al., 1993; Seidell et al., 2001). Thus it could be concluded that WHR is not an acceptable measure of change. Van der Kooy et al. (1993) identified numerous reasons for the relatively stability of this measure during weight loss including: 1) a relatively small weight loss; 2) the sites where waist and hip circumferences are measured; 3) an insufficient number of participants to detect relatively small changes in circumferences and their ratio and 4) waist and; hip circumference changing at the same rate.

When examining change month on month, significant changes were only observed in a limited number of traditional and alternative anthropometric measures during the initial months. For example BMI and mass, %BF and endomorphy showed significant decreases from baseline to month 2 then no further significant changes in these measures were evident. With %BF, $\Sigma 8SF$ and endomorphy decreasing significantly between baseline and month 2, and between months 2 and 3, with no further significant changes observed. An explanation for these results could be a decline in adherence to a programme that aims to promote weight loss, be it self-directed or a

more formal intervention. Dansinger et al., (2005) assessed the adherence and effectiveness of 4 popular diets and with each diet group (n=40) dietary adherence and self-reported adherence showed significant decline over time.

Furthermore, the results reported by Dansinger et al., (2006) show a significant reduction of between 1.2-1.3 kg from baseline to month 2 in all diet groups, however at 6 months, 2 of the diet groups showed no further change and 2 showed only a further 0.4kg decrease. This highlights the greater initial weight loss observed in the initial stages of weight loss, as identified in the present study. These results may have implications regarding the appropriate frequency of monitoring changes in body composition, indicating that following initial weight loss, measuring individuals on a monthly basis does not give sufficient time for changes in the composition of the body to occur. Monitoring provides an opportunity for positive reinforcement when weight loss/changes in body composition correspond to changes in behaviour (Butryn et al., 2007). Thus it is possible that the sampling frequency in the present study was too great to allow changes to be observed and thus decreased participants motivation. Bernadot (2006) states that assessing body composition two to four times a year is an appropriate frequency to determine and monitor body composition change in athletes. It could be hypothesised that this could also apply to an overweight/obese population as when examining body composition changes over longer time periods of 4 months, the current study identified significant changes in some variables.

Recognising that month on month change may not have provided sufficient time for changes in the composition of the body to occur, changes over long time periods were assessed. This elicited interesting findings, identifying significant changes in $\Sigma 8SF$, endomorphy and %BF from baseline to month 4, month 4 to month 8, and month 8 to month 12. In contrast, no other traditional or alternative anthropometric measure showed significant change during these time periods, with the exception of body mass from month 4 to month 8. These results reinforce the need for measures that account for

changes in body composition, as without this information false conclusions could have been made. For example, with just body mass and BMI information available it would have been concluded that participants in the present study had been unsuccessful in their weight loss attempts over the first four months. However, the results indicate that from baseline to month 4, $\Sigma 8SF$ showed a significant mean reduction of 15.7 ± 2.6 mm. Furthermore, endomorphy (relative fatness) and %BF also showed significant reductions over this time period.

Successful weight loss maintenance is associated with numerous factors, including greater initial weight loss that in turn enhances individual's motivation and self-efficacy (Elfhag & Rossner, 2005). Furthermore, it is a common place judgement that patients that do not achieve positive outcomes are more likely to drop out of treatment programmes (Ayyad & Andersen, 2000). As the present study has identified that $\Sigma 8SF$, endomorphy and %BF showed significant reductions without a concurrent significant reduction in body mass or BMI, providing this more detailed feedback regarding body composition changes may aid the maintenance of motivation and self-efficacy levels and reduce attrition. In the present study there was a 100% retention rate up until month 5, with an overall attrition rate of 36% by month 12 (Table 4.9) This is similar to findings of Womble et al., (2004) who reported a 34% attrition rate at both 16 and 52 weeks, in a study of 47 women enrolled in a commercial weight reduction program. In comparison to attrition figures reported in obesity literature, ranging from 20-80% (Clark et al., 1996; Farley et al., 2003), attrition in the present study was reasonably low. Furthermore, it has been hypothesised that emphasis on bodyweight sometimes diverts an individual's attention away from relevant aspects of energy balance behaviour (Cohen et al., 2005). Thus, by focusing attention on other parameters and transferring the emphasis from body weight, may also be beneficial in increasing individual's adherence to a healthier lifestyle.

This transference may also help address the dramatic disparity between recommended weight loss goals and individual's actual weight loss goals. Based on substantial evidence that many obesity-related conditions are improved with weight losses of 5% to 10% of initial body weight, changes of this magnitude are commonly recommended (Tate et al., 2001). In a review of individuals' goals and duration of weight loss attempts, Williamson et al., (1992) reported the average participant trying to lose weight wanted to lose 13.6kg (30 pounds). Foster et al. (1997), when assessing participants' perceptions of a 'reasonable' weight loss, found that in a population of 60 obese women goal weight averaged a 32% reduction in body weight. Unrealistic expectations were evident, with a 17-kg weight loss was considered disappointed; a 25-kg loss, was acceptable. Thus, focusing on other parameters may reduce participant's focus on unattainable weight loss goals.

4.3.8.1 Comparison of magnitude of change

Although $\Sigma 8SF$ showed the greatest magnitude of change during interim periods, this was not significantly greater than the magnitude of change in any other traditional or alternative anthropometric measure. However from baseline to month 12, both $\Sigma 8SF$ and endomorphy showed significantly greater magnitudes of change than body mass and WHR (Fig. 4.17). This suggests that these may be more useful measures to determine success and monitor change in overweight and obese individuals than body mass and WHR in the long term (i.e. with those individuals who remain with the programme). However, BMI and %BF showed comparable magnitudes of change to $\Sigma 8SF$ and endomorphy. Considering BMI first, this is a quick and easy measure to calculate and requires limited equipment and expertise (Rowland, 1990). However its main shortcoming, that the non-fat and fat masses are not accurately considered is well recognised (Baumgartner et al., 2003; Burkhauser & Cawley, 2008; Garcia et al., 2005; Norton & Olds, 1996). Furthermore, research has identified that this measure is not sensitive enough to recognise small yet clinically significant weight losses (Cook et al.,

2005). The results of the present study, identifying significant change in fat-related parameters during interim periods when BMI failed to show significant change, supports this view.

In contrast, %BF, a measure that represents change in the composition of the body, showed significant change at all interim periods and also showed comparable magnitudes of change to $\sum 8$ SF and endomorphy from baseline to month 12 (Fig.4.17). However, Ellis (2000) highlighted the population specific limitations between SF and %BF, reporting over 100 SF prediction equations published in current literature. Furthermore, the use of sophisticated techniques to measure %BF, such as MRI, DXA and densitometry, are impractical in most population studies (Snijder et al., 2006). A cheaper and relatively easier method to predict %BF is BIA, however in obese individuals with BMIs $>34\text{kg.m}^{-2}$, there is currently insufficient validation of BIA equations (Kyle et al., 2003). Additionally, despite these devices being marketed to the general public, their accuracy for the measurement of an individual's body fatness remains unclear (Ellis, 2000).

Therefore, whilst $\sum 8$ SF and %BF showed comparable magnitudes of change and both have been shown to be a sensitive measure of change in an overweight and obese population, using SF measures in their raw form is recommended as these measures are more reliable indices of regional fatness (Wells & Fewtrell, 2006) and are highly correlated with hydrostatically determined body density (Baumgartner et al., 2003) considered a valid reference method, yet one that is limited due to its expense and cumbersome nature (Stewart et al., 2003). Furthermore, although the measurement of SFs is subject to measurement error (Van Loan, 1997), with adequate training and adherence to protocols, this need not be equated with lack of validity (Stewart et al., 2003). Further research identifying specific skinfolds measures that are sensitive to change could overcome issues such as time constraints and the error associated with summation of measures.

The strength of the somatotype is that it summarises the physique as a unified whole, by combining the appraisal of adiposity, musculoskeletal robustness and linearity, into a three-number rating. No somatotype sub-component showed greater magnitude of change than BMI or %BF. Furthermore, endomorphy was the only sub-component to show greater magnitude of change than body mass and WHR and the only component to show significant change at interim periods. Thus, the benefits of utilising somatotype as opposed to traditional anthropometric measures to monitor weight loss are less apparent. Whilst somatotype accounts for changes in body composition, 10 measurements are required for its calculation requiring considerable time and expertise. Therefore, although at the individual level benefits may be gained by monitoring somatotype, the benefits of somatotyping do not appear sufficient to warrant the use of somatotyping in obesity research.

4.3.8.3 Limitations

A strength of the present study includes the longitudinal research design, however an inherent limitation of longitudinal research designs include high attrition rates. Although longitudinal analyses are less sensitive to missing data (Karason et al., 1997), to minimise any biasing effects results of those who dropped out were extracted, resulting in a relatively small sample size. Sampling bias is another pervasive problem in obesity research and obesity trials are often biased towards women (Moore et al., 2003). The current sample was predominantly female and did not represent a random sample of individuals, but rather a convenient sample of volunteers. This group therefore cannot be considered representative of the obese population in general.

Overall weight loss and body composition changes in the present study were modest, likely due to the participants following self-directed programmes. In light of this, it is important to acknowledge that despite the anthropometrist's satisfactory TEMs and coefficient of reliability ranges of 0.98-1.00,

measurement error may have confounded results, particularly as change was not calculated using confidence intervals.

A more serious methodological limitation of the present study is the lack of valid information regarding participants' diet and exercise habits throughout the duration of the study. It is well recognised that weight and fat-mass reductions are directly related to the individually induced energy deficits between energy intake and output (Stiegler & Cunliffe, 2006). Thus, the addition of this information may have provided an insight into the mechanisms that contributed to weight and body composition changes. Furthermore, no attempt was made to ascertain the status of participants prior to partaking in the studies. For example, details regarding previous weight loss attempts and duration of ongoing weight loss efforts. This could have impacted findings if for example, participants had previously lost a significant amount of weight, thus limiting the changes observed in the present study.

4.3.8.9 Future directions

Having established that $\Sigma 8SF$ is a sensitive measure of change that provides detail regarding the composition of the body this measure could be utilized to provide greater insight into gender differences during weight loss. Furthermore, due to expensive instrumentation and the practicality of methods such as DXA and densitometry, longitudinal studies have rarely tracked body composition changes long enough to detect age-based trends (Fantin et al., 2007). Thus future research could examine age-based trends in body composition change, utilising cheaper methods such as SF measures that overcome these barriers.

An additional avenue of research could examine the effect of seasonality on changes in body composition in order to identify critical time periods in which individuals are more susceptible to relapse and may require additional weight management support. Further analysis may also wish to explore patterns of

change in individual skinfold measures, in order to identify a smaller subset of skinfold measures that provide the same benefits, yet reduce economic costs from both a time and financial perspective. Finally, research should explore patterns of body composition change as a result of varying weight loss treatment modalities such as diet, exercise, or a combination there of, in order to identify the most efficacious weight loss method.

4.3.9 Conclusion

$\Sigma 8SF$ has been shown to be a sensitive measure that shows greater magnitude of change than mass and WHR. Furthermore it does not suffer the same limitations as BMI and %BF as it represents the composition of the body and is not limited by transformation from other variables. Additionally $\Sigma 8SF$ showed significant change that was unapparent when considering only weight-related parameters. This could provide a positive feedback mechanism for individuals that may in turn enhance motivation and self-efficacy levels leading to reduced attrition, a common issue in obesity research and treatment. Therefore, it is concluded that $\Sigma 8SF$, a measure that requires little instrumentation and can be routinely used in the field, could be utilised in an overweight and obese population to monitor weight loss. Conversely, the benefits of somatotype to monitor weight loss are less evident and should not be considered for routine use.

Finally, it is clear from the results of the present study that simple two wave 'before and after' designs may miss important fluctuations that occur in body weight and the composition of the body. It is concluded that future studies should consider the inclusion of more frequent monitoring to limit the possibility of false conclusions regarding success/failure, although monitoring at monthly intervals may be too frequent to observe a change and longer time periods (e.g. 3-4 months) should be considered.

5. STUDY TWO: Anthropometric measures and physical self-perceptions

This chapter provides an overview of the relationship between obesity and psychological health, an area that is less clearly delineated in comparison to the medical co-morbidity of obesity that is readily apparent (Steinbeck, 2004). The chapter introduces self-concept, focusing on the development of the multidimensional self-concept and more specifically, perceptions of the physical self that are thought to have important implications on psychological health (Carron et al., 2003). This is followed by a review of research examining the relationship between physical self-perceptions and body composition. Following the development of adequate instrumentation to assess physical self-perceptions, researchers have been able to establish links between physical self-perceptions and body composition; however this research has primarily focused on traditional anthropometric measures (Polman & Borkoles, 2007; Shaw et al., 2000; Van Vorst et al., 2002). Subsequently, the present study aimed to provide an understanding of the link between physical self-perceptions and alternative anthropometric measures. Relationships between traditional anthropometric measures and physical self-perceptions were compared with relationships between alternative anthropometric measures and physical self-perceptions. The relationship between changes in these measures were also examined, as identifying objective anthropometric measures that relate to physical self-perceptions, and understanding their interaction, may inform appropriate feedback mechanisms for improved management of overweight and obese individuals.

5.1 Introduction

Although the medical co-morbidity of obesity is readily apparent (Steinbeck, 2004), it has become increasingly clear that the problems associated with obesity are not restricted to its effect on physical health (Fontaine, 2002).

Although less clearly delineated, obesity is also thought to have an impact on a person's psychological well-being (Doll et al., 2000; Friedman & Brownell, 1995) and the psychological and social burdens of obesity can be significant (National Audit Office, 2001).

How humans perceive themselves has important implications for their psychological health (Carron et al., 2003). Two of the earliest self-perceptions studied were self-esteem (also known as self-worth) and self-concept (Gill & Williams, 2008). The terms are often used interchangeably however evident themes within literature suggest that self-concept is the overall descriptive perception of the self, and self-esteem is the evaluative aspect of the self (Butler, 2005).

Global self-esteem is underpinned by self-perceptions in many different life domains including work, family, spiritual and social (Thogersen-Ntoumani et al., 2005). Although all dimensions contribute to self-esteem, physical self-esteem, reflecting an individual's opinion of his or her appearance, strength, condition, co-ordination and other related aspects of the physical self (Schneider et al., 2008), seem to play a superlative role (Berger et al., 2002; Crocker et al., 2000, Fox, 2000). Consistently high relationships between aspects of the physical self and self-esteem are apparent in literature (Thogersen-Ntuomani et al., 2005) therefore the physical self was of interest in the present study.

There are many instruments used to evaluate the physical self (Buckworth & Dishman, 2002) including the Physical Self-Perception Profile (PSPP; Fox & Corbin, 1989), the Physical Self-Concept Scale (PSC; Richards, 1988), and the Physical Self-Description Questionnaire (PSDQ; Marsh et al., 1994). The theoretical frameworks behind these measures have the same generic structure (Fig. 5.1), with global self-concept and global self-esteem at the apex, overall physical self-worth at the domain level, and specific physical self-perceptions at the base (sub-domains) of the model (Crocker et al., 2006). The development of these multidimensional, hierarchical physical self-

concept instruments have overcome the limitations of early research that were reliant on instruments that did not clearly measure physical self-concept, or distinguish physical self-concept from other domains of global self-esteem (Burgess et al., 2006; Hayes et al., 1999; Marsh, 2002).

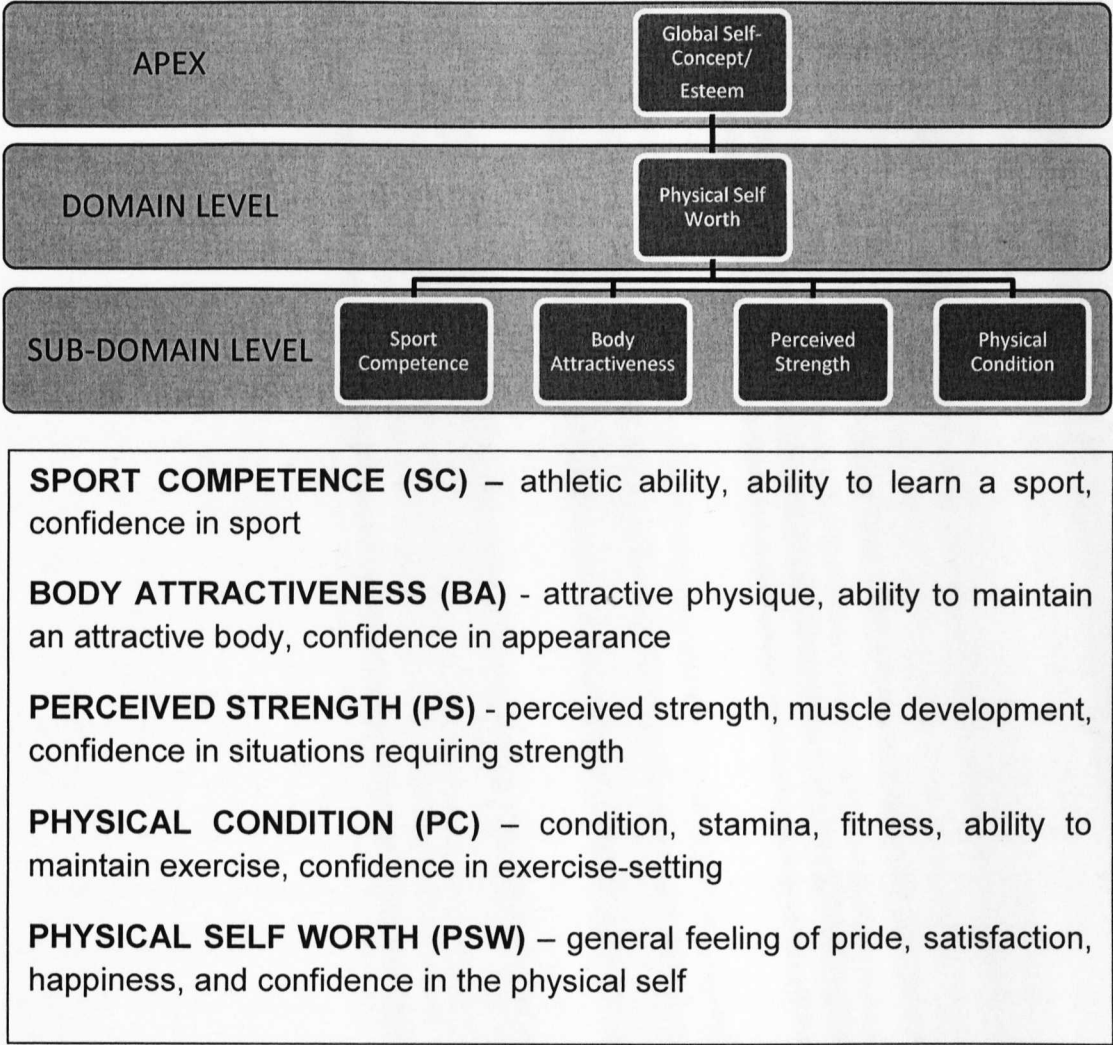


Figure 5.1. Hierarchical organisation of physical self-perceptions (Fox, 2001) and breakdown of sub-domain levels (Marsh, 1997).

It is the specific physical self-perceptions at the base of the model that separate the physical self-concept measures. The PSDQ (Marsh & Redmayne, 1994) measures nine elements of the physical self (strength, body fat, activity, endurance/fitness, sports competence, coordination, health, appearance, and flexibility). The PSC has six subdomains (body build, appearance, health, physical competence, strength, action orientation;

Marsh et al., 1994) and the PSPP (Fox & Corbin, 1989) measures perceptions of sport competence (SC), physical strength (PS), physical condition (PC), body attractiveness (BA) (Biddle & Mutrie, 2008) (Fig 5.1). In addition, the PSPP assesses the more global construct of physical self worth (PSW; Polman & Borkoles, 2007), defined as general feelings of pride, satisfaction, happiness, and confidence in the physical self (Hayes et al., 1999).

The PSDQ has been demonstrated to have good reliability (Marsh, 1996a), a well defined, replicable factor structure (Marsh et al., 1994) and good test-retest stability (Marsh, 1996b). However, the PSDQ was designed for use with adolescents and although Marsh and Redmayne (1994) have postulated that the instrument should also be appropriate for use with adults there is an absence of construct validity research to substantiate this claim. According to Ostrow's directory (1990), the PSPP is the strongest multi-dimensional physical self-concept instrument.

Initial evidence supporting the validity and reliability of the PSPP was demonstrated with a large sample of U.S. University Students (Hayes et al., 1999). However, Fox (1990) suggests the PSPP offers models of investigation of other groups and a study conducted by Page et al. (1993), has since established that the instrument is equally valuable for use within a British population. Additionally, the scale has not been found to be gender or age dependent which has important implications as age is thought to be an important moderator of the relationship between obesity and well-being (Hill, 2005). There is also evidence supporting the cross-cultural validity of the instrument (Page et al., 1993). Reasonably similar factor patterns for males and females have also been found with the PSPP, making gender comparisons possible (Fox, 1990).

Instruments used to measure physical self-perceptions such as SC, BA, PS, PC and PSW have been used extensively in research to examine age, gender (Hayes, 1999; McAuley et al., 1995; Sonstroem, 1998) and cross-

cultural differences (Page et al., 1993; Riley et al., 1998) in physical self-perceptions. The relationship between these physical self-perceptions (SC, BA, PS, PC and PSW) and exercise has also received attention (Thorgersen-Ntuomani et al., 2005), identifying that regular physical activity participation is moderately associated with positive physical self-perceptions (Fox, 2001). The relationship between changes in these variables over time has also been examined (Crocker et al., 2003; Daley et al., 2005; Ransdell et al., 2001) with a general consensus that exercise can improve physical self-perceptions. However, the mechanisms underpinning these changes are unknown, although Fox (2001) postulates several mechanisms, some tied to improvements in fitness and weight loss, and others linked to social significance and the exercise setting.

Body composition is another area that has been examined in relation to physical self-concept, both in terms of composition changes and cross-sectional comparisons (Polman & Brokoles, 2007; Shaw et al., 2000; Van Vorst et al., 2002). Research to date has been equivocal with some studies identifying a negative relationship between body mass and psychological well-being (Carr et al., 2007; Dong et al., 2004; Rippe et al., 1998; Schwartz & Brownell 2004; Wadden et al., 2006) and others finding non-significant associations (Istvan et al., 1992).

In a population of Caucasian women, aged 50-75 years, Shaw et al. (2000) examined body composition and physical self-concept changes as a function of strength training. The authors concluded that body composition was significantly related to overall physical self-concept. As a result of the strength training intervention total body fat decreased, however only decreases in leg fat were able to predict improvements in perceptions of physical appearance. Van Vorst et al. (2002) found similar results in a college population, identifying improvements in lower body strength, not upper body strength, were associated with improvements in physical self-concept.

More recently, Polman and Brokoles (2007) examined whether body composition and engagement in an exercise program influenced participant's physical self-perceptions. Significant decreases in %BF and BMI were apparent in participants who adhered to the exercise program, and these changes were associated with improved perceptions of PC and PS. Additionally decreases in %BF were correlated with BA, with decreases in WHR associated with the SC, BA and PS dimensions (Polman & Brokoles, 2007).

In a primary care exercise referral programme, involving 40-70 year olds, Taylor and Fox (2005) reported that changes in anthropometric measures were related to changes in physical self-perceptions. Conversely, in a mother and daughter sample following a 3-month fitness building exercise programme, Ransdell et al. (2004) found no relationship between changes in body mass and physical self-perceptions. The authors however suggested that this finding might be due to the limited changes in the body mass of the participants.

Previous research in the area of body composition has investigated the associations of physical self-perceptions with body composition parameters such as BMI, WHR and %BF (Polman & Borkoles, 2007; Shaw et al., 2000; Van Vorst et al., 2002). Little research has examined the association between somatotype and physical self-perceptions, with those that have focusing on body image. Body image is an integral component contributing to an individual's physical self-worth (Carron et al., 2003) and includes affective, cognitive and perceptual components (Thompson, 2004). It is usually conceptualised as incorporating body size estimation, evaluation of body attractiveness and emotions associated with body shape and size (Grogan, 2006). Thompson et al., (1999) identified 14 definitions of different components of body image; however this number has since dramatically increased (Stewart & Williamson, 2004). Consequently, numerous body image tools have been developed, all purporting to measure one or more of the body image dimensions (Grogan, 2006).

In a study of active and inactive adults, Bahram and Shafizadeh (2006) examined the relationship between body composition, including somatotype, and body image, focusing specifically on the appearance and fat sub-scales of the PSDQ. Significant moderate inverse correlations were found between the fat sub-scale and %BF and BMI. These findings confirm those of Sullivan (1993) and Eklund and Crawford (1994). Significant moderate inverse correlations were also evident between the fat sub-scale with endomorphy and mesomorphy and direct correlation with ectomorphy. This suggests that an adult's attitude toward their body emanate from their body size and type (Bahram & Shafizadeh, 2006). Although Bahram and Shafizadeh (2006) examined gender and activity level differences in their study sample, correlation analysis of body composition measures and PSDQ sub-scale scores were conducted on the study sample as a whole. Viviano (2001) identified that females tend to place greater importance on their appearance than men and dissatisfaction with body size and shape has been widely reported to be less pronounced in men than women (Kay, 2001). It has also been identified that women generally prefer an ectomorphic shape (Kay, 2001) with men desiring a mesomorphic build (Sands et al., 2004). Bahram and Shafizadeh (2006) identified a significant interaction of gender and activity level on the appearance sub-scale, thus separate correlation analysis may have identified different relationships to those presented.

As somatotype surveys on obese individuals have generally shown obese women to be considerably less ectomorphic than comparable samples of 'normal' women (Carter & Heath, 2005), with average ectomorphy scores 1.0-1.5 (Fett et al., 2006), obese women may experience greater degrees of body dissatisfaction, thus it is an area that warrants attention. Early research found little psychological predictive utility in somatotype variables, however Carter and Heath (2005) suggest this may be due to inadequate understanding of somatotyping and the use of different somatotyping methods. Furthermore, studies have correlated psychological variables with either components of somatotype or with the 'gestalt' somatotype (calculated as one reading measure) which may contribute to these findings.

Research in the area of body image has been based primarily on anthropometric representations that are rarely based on genuine anthropometric measurements (Stewart et al., 2003). Examples of methods that have been used in current research to construct these representations include computer graphic methods (Gruber et al., 2001; Kagawa et al., 2006; Letosa-Porta et al., 2005), linear analogue and figural drawing scales (Cachelin et al., 2002; Gardner & Brown, 2010; Maximova et al., 2008) and questionnaires (Cooper et al., 2006; Riley et al., 1998). Limitations of these methods have been well documented. For example, no single questionnaire can broadly measure a continuum of body image disturbance (Cash et al., 2004). Furthermore, by altering arc sizes and overlapping ellipsoids (Schlundt & Bell, 1993) computer generated techniques have allowed individuals to alter body silhouettes to make them thinner or fatter. However, these techniques have failed to produce realistic images (Stewart et al., 2003). Benson et al. (1999) suggest this is due to the simple reason that a real, recognisable body image is not presented. Distortion can also be unrealistic and limited in range and direction (e.g. thinner, fatter) and cannot measure specific body parts (Benson et al., 1999).

The need for addressing specific body areas, not just the global silhouette, is well recognised (Aclaniz et al., 2003). Stewart et al. (2003) have identified that assessment of body image can proceed from detailed assessment of the body, yet is frequently overlooked. Andersen et al. (2006) suggest that the use of objective anthropometric and body composition measures, which are more sensitive indexes of physical changes than body mass, may provide greater insight into the relationship between physical changes and changes in physical self-perceptions.

5.2 Aims and Hypotheses

5.2 Aims and Hypotheses

Increasing existing awareness of factors influencing psychological health in an overweight/obese population may be helpful in terms of public health (Laforest et al., 2009). Identifying objective anthropometric measures that relate to physical self-perceptions, and understanding their interaction, may inform appropriate feedback mechanisms for improved management of overweight and obese individuals. Study Two therefore aimed primarily to examine and compare the relationship between traditional and alternative anthropometric measures with physical self-perceptions (as measured by the PSPP) in a population of overweight and obese individuals. Secondly, the study examined changes in PSPP constructs over time and then moved forward to investigate the association between changes in traditional and alternative anthropometric measures with changes in PSPP constructs. The following alternative (experimental) hypotheses were formulated:

H₅) Alternative anthropometric measures would show stronger correlation with PSPP constructs compared to traditional anthropometric measures with PSPP constructs.

H₆) PSPP constructs would improve over time.

H₇) Changes in alternative anthropometric measures would show stronger correlation with changes in PSPP constructs compared to changes in traditional anthropometric measures with changes in PSPP constructs.

Many studies examining changes in physical self-perceptions have investigated these changes over different time periods ranging from 6-12 weeks (Burgess et al., 2006; Polman & Borkoles, 2007; Rippe, et al., 1998) to 4-12 months (Crocker et al., 2003; Daley et al., 2005; Schneider et al., 2008; Teixeira et al., 2006). However it is not clear what the optimal time lag to assess causal effects in physical self-perceptions is (Crocker et al., 2006). Welk and Eklund (2005) suggest that longitudinal designs examining

changes in physical self-perceptions over time may be useful in determining the relevance of physical self-perceptions on health-related outcomes. Therefore, to advance traditional cross-sectional research on the physical self, the current study collected data over a year, in order to examine how perceptions of the physical self change over a longer time period.

However, as identified in Chapter 3.5.1 individual change takes place continuously over time and should not be viewed as a 'before and after' phenomenon (Willett, 1994). Furthermore, it is well established that weight loss maintenance, defined as intentional weight loss that has subsequently been maintained for at least 6 months (Elfhag & Rossner, 2005) is problematic. Weight cycling, whereby individuals repeatedly lose and regain weight, is another common problem experienced by individuals trying to lose weight (Brownell & Rodin, 1994). As the current study aimed to examine how objective anthropometric variables and physical self-perceptions change over time, examination over shorter-time periods may identify relationships that would not be apparent when examining change over a year. Changes in self-perceptions have been evident in programmes longer than 8 weeks in duration (Andersen et al., 2006). Therefore, the relationship between change in traditional and alternative anthropometric measures and PSPP constructs at the following intermittent time periods; from baseline to month 4, months 4 to 8, and month 8 to 12, were also examined.

5.3 Methods

5.3.1 Study design and participants

Ethical approval for Study Two was received from the BioSciences Research Ethics Committee of the University of Portsmouth. A total of 60 participants, male (n=10) and female (n=50) between 35-79 years completed a shortened version of Fox and Corbins (1989) PSPP and underwent anthropometric profiling. Please refer to Chapter 4.2.2.1 for details regarding determination of sample size *a priori*, and to Chapter 4.2.3 for details regarding recruitment

processes, inclusion and exclusion criteria and preliminary screening methods.

5.4 Procedures

5.4.1 Anthropometric Data Collection

All anthropometric data were collected using the same protocol described in Chapter 3.1 and the data handling procedures described in Chapter 4.2 were followed to allow calculation of BMI, WHR, %BF, $\Sigma 8SF$ and the three somatotype sub-components; endomorphy, mesomorphy and ectomorphy. Data were collected on 4 separate occasions; at baseline and at months 4, 8 and 12.

5.4.2 Use of the PSPP

The PSPP has been subjected to extensive psychometric scrutiny during its development and the reliability, integrity and hierarchical organisation of the subscales have been confirmed (Page et al., 1993). A particular strength of the PSPP is its content validation (Marsh, 1997). The factor structure appears to be robust across populations, and subscales are internally consistent, which encourages confidence in the normative properties of the scale (Fox & Corbin, 1989). The Likert-type scale is familiar to most individuals (Buckworth & Dishman, 2002) and the structured alternative format of the PSPP has been shown to reduce social desirability responding (Fox, 1998; Fox & Corbin, 1999), a problem which has plagued self-esteem research in the past (Marsh, 1997). Furthermore, as an indicator of change in mental well-being, the PSPP is thought to have particular relevance to exercise and weight management settings (Page et al., 1993). Therefore, the PSPP was the psychological instrument used in the current investigation.

5.4.3 PSPP data collection

The PSPP has 5 factors (PC, PS, SC, BA, PSW) with each factor consisting of 6 items. The item score can range from 1 (low) to 4 (high) on a structured-alternative scale (Hayes et al., 1999). Respondents first select which of two contrasting statements relates to them, then decide whether the statement is 'sort of true' or 'really true' for them. A total subscale score of 6 (low) to 24 (high) is available for each factor. A copy of the PSPP and sheet for recording scores by hand are provided in Appendices 11 and 12, respectively. Previous studies have identified that the PSPP constructs PS and SC, are most susceptible to change through exercise (Fox, 1997). As the aim of the study was not exercise, strength or sport focused, and given the nature of the sample (individuals with some degree of overweight or obesity), the SC and PS items were removed to avoid redundancy. Fox and Corbin (1989) suggest that satisfaction with appearance is the domain of self-worth most affected by obesity (Hill, 2005) and perceptions of body appearance and physical self-worth are linked to weight management (Crocker et al., 2006). Therefore the construct of BA, PC and PSW remained.

Sample items characterising each of the scales used are as follows: "I am often admired because my physique/figure is considered attractive" (BA esteem); "I feel confident that I maintain excellent conditioning and fitness" (PC esteem) and "I feel extremely proud of who I am and what I can do physically (PSW esteem). All PSPP data were collected according to the time scale described above in Chapter 5.4.1, immediately following anthropometric profiling. Verbal feedback of all anthropometric changes were provided prior to completion of the questionnaire.

5.4.4 Statistical Analyses

Statistical tests of normality and difference for anthropometric data have previously been described in Chapter 4.2.3.1, thus the remainder of this

section will discuss the analysis methods applied to PSPP data and detail the correlation techniques used to examine the relationships between anthropometric and PSPP data.

5.4.4.1 Tests of normality

Evaluation of skewness and kurtosis identified that the distribution of PC and BA were normal ($z(\text{skew})=2$, and $z(\text{kurtosis})=1.5$; $z(\text{skew})=1.8$, $z(\text{kurtosis})=1.5$), however PSW was not normal ($z(\text{skew})=2.9$, and $z(\text{kurtosis})=3.5$). Kolmogorov-Smirnov's test showed that both PC and BA were normally distributed ($D(60)=0.105$, $P=0.095$, and $D(60)=0.098$, $P=0.200$) and that PSW was not normally distributed ($D(60)=0.158$, $P=0.001$). Logarithmic transformation of PSW did not improve distribution, however graphical plots indicated linear patterns and the sample size of 60 was considered sufficient to invoke the central limit theorem (Boslaugh & Watters, 2008) thus the decision to use parametric tests was taken.

5.4.4.2 Tests of difference

A Wilk's Lambda multivariate repeated measures ANOVA, with Bonferonni adjustment, was conducted to test H_2 , with time as an independent factor and the PSPP constructs PC, BA and PSW as dependent variables. Mauchly's test indicated that PC, BA and PSW violated assumptions of sphericity ($X^2(5) = 19.092$, $P = 0.002$; $X^2(5) = 11.104$, $P = 0.049$; and $X^2(5) = 21.860$, $P = 0.001$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.83$).

5.4.4.3 Correlation analysis

A Pearson's Correlation Coefficient was used to examine the correlation of anthropometric measures with PSPP construct scores at baseline and the inter-correlation between PSPP constructs. Correlation coefficients <0.29 were defined as weak, between 0.3 and 0.69 moderate and >0.7 strong

(Jackson, 2009). Any time point could have been chosen to examine the correlation between anthropometric measures and PSPP construct scores, however similar strength correlations were observed at all time points, thus only baseline relationships are presented.

Correlation analysis was also conducted between calculated changes (between baseline and month four, month 4 to month 8, month 8 to month 12, and baseline to month 12) in all anthropometric measures and PSPP construct scores. Change was calculated as the difference between initial and final time point.

It has been argued that the analysis of absolute change between two time points is not appropriate when there are differences at baseline between the intervention and control group (Twisk & Proper, 2004). To account for these differences, methods such as analysis of covariance and analysis of 'residual change' are often used (Twisk & Proper, 2005). However, the present study is not comparing an intervention group with a control group. Furthermore, when only two waves of data are available, calculating difference scores is intuitively appealing, easy to compute and provides an unbiased estimator of true change (Olweus & Alasker, 1994; Willett, 1997), thus difference scores were used in the present analysis.

5.5 Results

Data are presented for participants who attended all anthropometric measurement sessions and completed the PSPP questionnaire (n=60). Baseline demographic, traditional and alternative anthropometric measures have previously been provided in Table 4.8.

5.5.1 Baseline relationships between anthropometric measures and PSPP component scores

Three of the four traditional anthropometric measures showed significant moderate relationships with at least one PSPP construct at baseline (Table 5.1). BMI showed significant inverse correlation with all PSPP constructs, with the strongest inverse relationship evident between BMI and BA ($r(60)=-0.53, P<0.05$). Body mass also showed a significant moderate negative association with BA ($r(60)=-0.43, P<0.05$) however did not show a significant relationship with either PC or PSW ($r(60)=-0.23, P>0.05$). WHR showed a significant positive correlation with PC however this was weak. %BF showed significant correlation with all PSPP constructs with similar strength relationships seen in PC and BA and the weakest relationship evident between %BF and PSW.

Three of the four alternative anthropometric measures also showed significant moderate relationships with at least one PSPP construct at baseline (Table 5.1). $\Sigma 8SF$ and endomorphy showed significant moderate negative correlations with PC and BA ($r(60)=-0.45, P<0.05$ and $r(60)=-0.54, P<0.05$, respectively). Significant inverse correlation was also observed between $\Sigma 8SF$ and PSW and endomorphy and PSW (Table 5.1). In contrast, the somatotype sub-component mesomorphy showed significant negative correlation only with BA ($r(60)=-0.43, P<0.05$). Ectomorphy failed to show a significant association with any PSPP construct.

Inter-correlations between PSPP constructs indicated that PC showed a strong significant positive correlation with BA and PSW (Table 5.1). BA and PSW demonstrated the strongest association of all PSPP constructs ($r(60)=0.78, P<0.05$).

Table 5.1. Relationship (Pearson’s correlation coefficient) of anthropometric indices with PSPP construct scores at baseline (n=60)

	PC	BA	PSW
TRADITIONAL			
BMI (kg.m ⁻²)	-0.29*	-0.53*	-0.28*
Mass (kg)	-0.23	-0.43*	-0.23
WHR	0.26*	0.04	0.17
%BF	-0.50*	-0.53*	-0.34*
ALTERNATIVE			
Σ8SF (mm)	-0.45*	-0.54*	-0.35*
Endomorphy	-0.45*	-0.54*	-0.34*
Mesomorphy	-0.21	-0.43*	-0.24
Ectomorphy	0.19	0.23	0.02
PSPP CONSTRUCTS			
Physical Condition	-	0.63*	0.63*
Body Attractiveness	0.63*	-	0.78*

*P<0.05

5.5.2. Change in PSPP measures over time

Collectively the PSPP constructs showed significant change over time ($F=3.742_{9,512}, P<0.05, 1-\beta=0.94$). All PSPP constructs showed significant increases between baseline and month 4, and from baseline to month 12 (Fig.5.2). Additionally, BA showed significant change from baseline to month 8, however no PSPP constructs showed significant changes between other time points, e.g. month 4-8, 8-12, or 4-12 (Fig. 5.2).The highest baseline score was seen in PC (12.8 ± 0.5), with the next highest score observed in PSW (11.6 ± 0.4) and the lowest in BA (10.6 ± 0.4). The greatest improvements were observed in BA with an increase of 1.1 ± 0.3 from baseline to month 4 and an overall improvement of 2.0 ± 0.4 . Smaller, significant changes were observed in PC and PSW over the testing period, of 1.7 ± 0.5 and 1.5 ± 0.4 , respectively (Fig. 5.2).

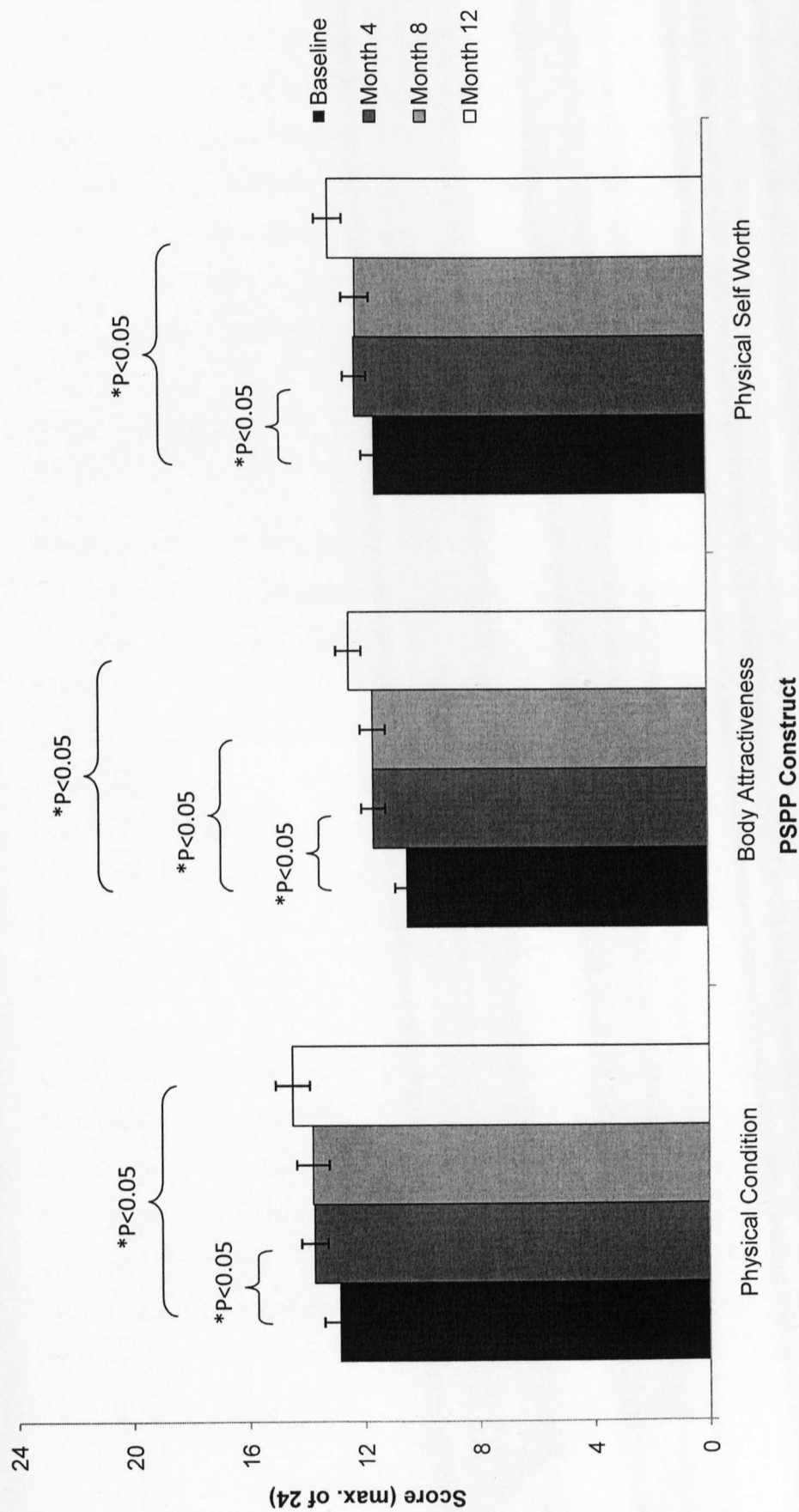


Figure 5.2: Mean PC, BA and PSW scores over time (n=60).
Vertical bars show standard errors of the mean

Prior to conducting an analysis to establish a causal relationship between changes in anthropometric measures and changes in PSPP constructs, it was first necessary to establish whether these measures changed significantly over time. The results of Study One, Part B have already established that all anthropometric variables, with the exception of WHR and ectomorphy, changed significantly over time (Figs. 4.8-4.9). Additional analysis confirmed that during interim periods (i.e. baseline-month 4, month 4-8, and month 8-12), $\Sigma 8SF$, endomorphy and %BF were the only anthropometric variables that changed significantly (Table 4.9).

5.5.3. Relationship between changes in anthropometric measures and changes in PSPP component scores

When examining change in traditional anthropometric measures and PSPP constructs from baseline to month 12, significant inverse associations between BMI, mass, and %BF were found with the PSPP construct PC (Table 5.2). WHR was the only anthropometric measure to show a significant positive association with BA ($r(60)=0.30, P<0.05$). However all associations observed between changes in traditional anthropometric measures and changes in PSPP constructs were either weak or only just reached moderate strength. For example, change in BMI, mass and %BF were significantly correlated with change in PC, however the strength of these correlations were <0.3 (Table 5.2).

When examining change in alternative anthropometric measures and PSPP constructs from baseline to month 12, a significant inverse correlation between endomorphy and PC was apparent (Table 5.2). However, this was also weak ($r(60)=-0.25, P<0.05$). No other significant correlations were observed between changes in alternative anthropometric measures and PSPP constructs. Changes in PC and BA showed strong correlation to changes in PSW ($r(60)=0.65, P<0.05$, and $r(60)=0.72, P>0.05$, respectively).

Table 5.2. Relationship (Pearson's correlation coefficient) of change in anthropometric indices with change in PSPP construct scores from baseline to month 12 (n=60)

	Baseline – Month 12		
	PC	BA	PSW
TRADITIONAL			
BMI (kg.m ⁻²)	-0.26*	-0.11	-0.16
Mass (kg)	-0.27*	-0.09	-0.15
WHR	0.13	0.30*	0.22
%BF	-0.28*	-0.06	-0.05
ALTERANTIVE			
Σ8SF (mm)	-0.14	-0.00	-0.05
Endomorphy	-0.25*	-0.03	-0.02
Mesomorphy	-0.14	-0.03	-0.04
Ectomorphy	0.10	0.00	0.09
PSPP CONSTRUCTS			
Physical Condition	-	0.63*	0.65*
Body Attractiveness	0.63*	-	0.72*

*P<0.05

When examining changes between interim periods, the strongest associations between change in anthropometric variables and change in PSPP constructs occurred between months 8 to 12 (Table 5.3), however the PSPP constructs did not show significant change during this time period (Fig. 5.2). As BMI and mass decreased BA scores increased ($r(60)=-0.40, P<0.05$). Decreases in %BF were associated with increases in PC, BA and PSW. Reduction in Σ8SF and endomorphy both correlated with increases in PC, BA and PSW with the strongest associations evident in endomorphy. Between months 4 and 8 only two significant but weak correlations were observed, with reduction in BMI and mass correlating with increases in PSW ($r(60)=-0.27, P<0.05$ and $r(60)=-0.30, P<0.05$, respectively). Significant correlations were also observed between baseline and month 4 however these were again weak. The strongest relationships were evident between change in BMI, mass, and endomorphy with change in PC, showing similar strength relationships between -0.26 and -0.27. Decreases in endomorphy also correlated with increases in BA. In contrast, increases in ectomorphy correlated with increases in BA ($r(60)=0.26, P<0.05$). Weak correlations were also observed between decreases in BMI and mass with increases in PSW.

Table 5.3. Relationship (Pearson's correlation coefficient) of change in anthropometric indices with change in PSPP construct scores between three separate time periods; baseline-month 4, months 4-8, months 8-12 (n=60)

	Baseline – Month 4				Month 4 - Month 8				Month 8 – Month 12			
	PC	BA	PSW		PC	BA	PSW		PC	BA	PSW	
TRADITIONAL												
BMI (kg.m ⁻²)	-0.27*	-0.16	-0.15*		-0.25	-0.09	-0.27*		-0.18	-0.40**	-0.18	
Mass (kg)	-0.26*	-0.15	-0.14*		-0.23	-0.09	-0.30*		-0.19	-0.40**	-0.19	
WHR	0.14	-0.22	-0.12		-0.11	-0.21	-0.20		0.01	-0.06	0.01	
BF(%)	-0.24	-0.17	-0.06		-0.25	-0.08	-0.19		-0.31*	-0.38**	-0.31*	
ALTERNATIVE												
Σ8SF(mm)	-0.23	-0.19	-0.02		-0.15	-0.05	-0.07		-0.42**	-0.45**	-0.42**	
Endomorphy	-0.27*	-0.25*	-0.01*		-0.23	-0.15	-0.20		-0.48**	-0.51**	-0.48*	
Mesomorphy	-0.02	-0.18	-0.14		-0.11	0.05	-0.20		-0.05	-0.14	-0.05	
Ectomorphy	0.20	0.26*	0.12		0.07	0.19	0.01		0.23	0.31*	0.23	

*p<0.05

**p<0.01

5.6 Discussion

The main aim of the present study was to identify the relationship between PSPP constructs and anthropometric indices and examine whether changes in alternative anthropometric measures were more strongly correlated with changes in PSPP constructs than changes in traditional anthropometric measures.

5.6.1 Baseline relationships between anthropometric measures and PSPP component scores

At baseline all PSPP constructs were significantly related to at least one anthropometric measure (Table 5.1). Perceived PC and BA were also positively correlated with each other, and with PSW, thus supporting the hierarchical nature of physical self-perceptions proposed by Fox and Corbin (1989).

Moderate significant inverse correlations were observed between the traditional anthropometric variables BMI, mass and %BF ($r=-0.43$ to -0.53) with the PSPP construct BA (Table 5.1). These results are in agreement with research evidence that identifies that BMI, mass and % body fat correlate closely with BA (Bahram & Shafizadeh, 2006; Caruso & Gill, 1992; Eklund & Crawford, 1994; Welk & Eklund, 2005; Sullivan, 1993). In contrast to research by Kay (2001), who proposed that girth ratios such as the WHR may be useful anthropometric correlates of body dissatisfaction, the present study showed no significant correlation between WHR and BA. This result confirms those of Mitchell et al. (2003) who also found no relationship between WHR and BA when examining body image and anthropometric measures in exercising and non-exercising women. It has been reported that BMI explains significantly more variance of BA data than WHR (Tovee et al., 1998; Smith et al., 2007). Therefore, this may provide explanation for the lack of association between WHR and BA in the present study.

However, whether BMI or WHR is a more important factor of attractiveness is an ongoing debate (Perilloux et al., 2010) and criticisms have been made that the greater influence of BMI on BA is a result of research using stimuli with a wide range of BMI's and a relatively restricted range of WHR's (Dixon & Baogou, 2010). However, WHR ranges were favoured in a study conducted by Tovee et al. (2002), with BMI ranges limited to 0.5SD either side of the sample mean and WHR ranges averaging 1.65SD. Despite the relative ranges favouring WHR, BMI was still found to be more important in explaining variance in BA.

Bahram and Shafizadeh (2006) identified significant inverse correlations between BA and endomorphy and mesomorphy. The results of the present study confirm these findings, with the alternative anthropometric measures of endomorphy and mesomorphy also showing significant moderate inverse correlations with BA ($r=-0.43$ to $-0.53, P<0.05$). In addition $\Sigma 8SF$ showed a significant moderate inverse correlation with BA ($r=-0.54, P<0.05$). Western cultures promote physical attractiveness and leanness as important standards of beauty and success (Philips & Drummond, 2001). Research indicates that women are mainly concerned with losing fat (Norton & Olds, 1996), and desire a less muscular body (Oehlhof et al., 2009). As the study population in the present study consisted primarily of females this may explain the inverse correlations observed in both endomorphy and mesomorphy. The strength of correlations observed between both traditional and alternative anthropometric measures with the PSPP construct BA in the present study were very similar. This suggests that the influence of overall morphology on BA, as reflected by somatotype, is as important as the influence of the physical characteristics of BMI and body mass.

Body dissatisfaction is not only a consequence of obesity; it can also be causative in weight gain in adults through unhealthy restrictive dieting behaviours (Goldfield et al., 2007). There is strong research evidence to suggest that low perception of body image is a strong motivator for exercise, particularly among women (Courneya & Hellsten, 1998; Davis et al., 1995).

However, when examining body image concerns related to physical activity participation, Zabinski et al. (2001) identified that physical activity interventions may increase concerns in women. These negative consequences occurred despite the intervention consisting of content designed to prevent concern over dieting and the importance of weight. Therefore, the results of the present study identifying associations between high BMI, mass, $\Sigma 8SF$ and somatotype scores with low BA scores, suggest that interventions that aim to reduce weight and improve lifestyle should also aim to enhance perceptions of BA. Furthermore, the assessment of potential negative side effects in weight loss and lifestyle interventions, such as increased concern about body image (Zabinski et al., 2001), unrealistic weight loss expectations (Foster et al., 1997), and increased body image concerns following relapse (Kayman et al., 1990), should be considered.

All traditional anthropometric measures showed significant inverse correlation with PC however those observed in BMI, mass and WHR were weak ($r < 0.30$). Comparable strength correlations between BMI and PC were observed by Acsi (2005) and Taylor and Fox (2005). %BF, $\Sigma 8SF$ and endomorphy showed significant moderate correlations with PC (Table 5.1). The stronger correlations observed in anthropometric measures related to body fat suggest that individuals relate perceptions of their physical condition to measures related to fat as opposed to weight related parameters of BMI and body mass. Improvements in specific physical self-perceptions, for example PC and BA are thought to generalise to PSW (Knappen et al., 2005). Two traditional and two alternative anthropometric measures showed significant negative correlation with PSW. $\Sigma 8SF$ and endomorphy both showed moderate strength association ($r = -0.34, P < 0.05$ and $-0.35, P < 0.05$ respectively). %BF showed a similar strength correlation although that observed with BMI was weaker.

Overall, strength of associations between traditional and alternative measures with the PSPP constructs BA and PSW were comparable. The highest correlation observed in relation to PC was with the traditional

anthropometric measure %BF. However, this was of a similar level to alternative anthropometric measures; $\Sigma 8SF$ and endomorphy. Thus H_4 , that stronger correlations will be observed between alternative anthropometric measures and PSPP constructs compared to traditional anthropometric measures, is rejected.

5.6.2 Change in PSPP measures over time

McAuley et al. (2000) examined changes in physical self-perceptions over a 12 month period (6 month exercise intervention and 6 month follow up). Change in BA over the 12 month period in the walking intervention group showed comparable change to those observed in BA in the present study, both showing a significant increase of 1.1 ± 0.3 (Fig.5.2). Increases in PSW over the 12 month period were slightly higher in the present study (1.5 ± 0.4) compared to the 1.2 increase observed by McAuley et al. (2000), however this may be a result of differences in baseline scores. The walking groups baseline PSW was 1.7 higher than the baseline PSW in the present study. Baseline PC scores in the present study were comparable with those in the study by McAuley et al. (2000) however smaller increases were observed in the present study (Fig.5.2). This could be due to the participants in the study conducted by McAuley et al. (2000) following a structured program of regular walking, increasing both in intensity (beginning at 50-55% of VO_2 max and increasing to 65-70% of VO_2 max by the midpoint of the program) and duration (beginning at 10-15 minutes per session three times a week and increasing up to 40 minutes per session three times a week). In comparison, whilst objective measures were not recorded, the participants in the present study that were taking part in structured walks attended on average 1-2 walks per week of a relatively low intensity (~metabolic equivalent (MET) value of 3-4), with those that followed home exercise programmes reporting low activity levels estimated <3 METs. Therefore, the participants' activity levels may not have been sufficient to result in changes in their perceptions of their PC.

In the first interim period (baseline to month 4) significant improvements were observed in all PSPP constructs (Fig.5.2). These results are in contrast to those observed by Caruso and Gill (1992) who found no significant changes in physical self-perceptions over a 10 week exercise program of exercising and non-exercising students. Asci et al. (1998) also reported similar non-significant associations. Taylor & Fox (2005) found significant improvements in PC, BA and PSW over a 16 week period, however, the PSPP scores analysed in the study were derived for each participant by summing responses and dividing by the number of items in the scale. Thus, comparison of item scores is not possible. To summarise, all PSPP constructs showed significant improvement over the 12 month period (Fig.5.2), and showed significant improvements from baseline to month 4, thus H_5 is accepted.

5.6.3 Relationship between changes in anthropometric measures and changes in PSPP component scores

Although significant associations were apparent between change in anthropometric measures and change in PSPP constructs over 12 months, these were all of weak value and observed in traditional anthropometric measures, with the exception of endomorphy (Table 5.2). This finding is in direct contrast to H_6 , thus it is rejected. In contrast to the non-significant association between WHR and BA observed at baseline in the present study, change in WHR was the only anthropometric variable to show significant correlation with change in BA. This correlation was approaching moderate strength. However, although BA significantly improved over the 12 month period, WHR did not change significantly over this time period. Thus, this should be considered when interpreting the relationship between change in WHR and change in BA. As WHR is less sensitive to weight gain/loss than waist and hip girths taken separately (Seidell et al., 2001; Vazquez et al., 2007), this may explain the lack of significant change and future studies should consider the analysis of these circumference measures separately, in addition to WHR.

Taylor and Fox (2005) examined changes in anthropometric data (including skinfolds) and changes in physical self-perceptions over a 37 week period. Sum of 4 skinfolds, including biceps, triceps, subscapular and iliac crest skinfolds, showed significant negative correlation with PC ($-0.46, P < 0.05$) and BA ($-0.41, P < 0.05$), but no significant association with PSW. In contrast, the present study found no association between skinfold measures and any PSPP construct, albeit using $\Sigma 8SF$. Examining change in individual skinfold measures may have elicited interesting findings, as evidenced by Taylor and Fox (2005) who found change in triceps skinfold to show significant moderate inverse correlation with PSW, PC and BA. Furthermore, in the study by Taylor and Fox (2005) participants were participating in a primary care exercise referral programme. Although details are not provided regarding the specific nature of the exercise programmes, this is likely to have been more focused than the self-directed programs followed by the current study participants and this may have contributed to the contrasting findings.

There was no association between changes in PSW with changes in any anthropometric measure and although significant inverse correlations were observed between change in BMI, mass, endomorphy and %BF and change in PC these were all weak (Table 5.2). A possible explanation for the weak relationships observed between changes in anthropometric measures and improvements in PSPP constructs may be due to the level of weight loss achieved. Research has identified that moderate weight loss (5-10% of initial weight) can lead to improvements in mood, body satisfaction and self-confidence (Hill, 2005). It is important to note that whilst participants achieved a significant weight loss, the mean reduction was 3.9 ± 0.9 kg and most participants were still classified as overweight or obese, thus participant perceptions of their physical self may not have undergone noticeable changes. Therefore the perceptions of themselves in terms of BA and PC may not have altered. Furthermore, the degree of importance attached to each of the constructs may also play a role in examining physical self-perceptions (Sonstroem, 1998). For example, research by McAuley et al.

(1996) indicated that the importance placed on BA was found to be significantly less important at the end of a 20 week intervention than pre-programme. As a result of participating in the present study, participants may have realigned their perceptions of their physical self and placed more or less degree of importance on particular aspects, thus may provide partial explanation for the lack of correlation between changes in anthropometric measures and changes in PSPP constructs. Marsh and Sonstroem (1995) found little support for the contention that importance ratings influence self-esteem ratings, however limited exploration of such propositions exist (McAuley et al., 1996).

Although from baseline to month 4 significant correlations were observed between changes in BMI, mass endomorphy and ectomorphy, with changes in all PSPP constructs, these were weak (Table 5.3). From month 4 to month 8 changes in BMI and mass showed significant correlations approaching moderate strength with changes in PSW, however these measures showed no significant change over this time period. Thus, these relationships should be interpreted with caution. Van Vorst et al. (2002) found that in a population of preparation stage exercisers; defined as seriously considering changing their exercise behaviour within the next month (Prochaska & Velicer, 1997); improvements in physical self-concept levels were associated with improvements in lower body strength, but not upper body strength. Similarly, Shaw et al. (2000) found decreases in total body fat during a strength training intervention however found that only decreases in leg fat were related to perceptions of physical appearance. In light of these findings, a possible explanation for the lack of association between changes in anthropometric measures and changes in physical self-perceptions observed in the present study may be that the anthropometric measures used did not focus on specific body areas.

Furthermore, the PSPP instrument used is not body area specific, including generic statements such as 'I feel that compared to most, I have an attractive body'. Thus it may not have identified significant associations. The PSDQ

measure may have identified significant associations as it contains items that are more specific regarding perceptions of attractiveness, such as 'my waist is too large' and 'I have too much fat on my body' (Marsh et al., 1994). However, this is a 70-item questionnaire and although the appropriateness for its use in a range of populations has been established (Marsh et al., 2002) results suggest that 17% of the items are biased in favour of men, and 23% in women (Fletcher & Hattie, 2005) and the instrument's validity in an obese population has not been firmly established (Marsh et al., 2005). Another possible explanation for the lack of associations in the present study may be due to the importance an individual places on physical self-perceptions. For example, evidence of a relationship between body composition and physical condition may be absent in individuals who place no importance in physical condition, and fitness. Although the use of perceived importance profiles have yielded mixed findings (Fox & Wilson, 2008), efforts to assess perceived importance may have important practical implications in physical self-perception research.

Although mesomorphy and ectomorphy showed significant change pre and post, these somatotype subcomponents did not show significant change at interim periods. It has been identified that women generally prefer an ectomorphic shape (Kay, 2001) with men desiring a mesomorphic build (Sands et al., 2004). As these components did not change significantly in the present study during interim periods, this may provide explanation for the lack of association between changes in these components with changes in PSPP construct scores.

Few significant correlations were observed between changes in anthropometric measures and change in physical self-perceptions from baseline to month four (Table 5.3), however all PSPP constructs showed significant improvement over the time period (Fig.5.2) The opposite was observed when examining changes from month 8 to month 12, identifying significant moderate strength relationships between changes in anthropometric measures and changes in PSPP constructs, yet no

significant change in physical self-perceptions over the time period. This pattern could reflect the function of individual's physical self-perceptions over time, starting as a cognitive function then focusing perceptions in relation to physical changes, in relation to objective measures.

There is evidence to suggest that body image may be cognitive rather than physical (Schwartz & Brownell, 2004), in that it may not be associated with actual weight but may be more strongly associated with perception of weight (Hill, 2005). For example, Cash et al. (1990) have studied a range of eating and body image measures in individuals who were currently, formerly, or never overweight. The positive body image obtained by individuals who were previously overweight and subsequently lost weight, did not reach the positive body image levels of those who were never overweight. Furthermore, although individuals who underwent bariatric surgery reported greater satisfaction with their own body, decreased feelings of fatness and increased feelings of body attractiveness 3 years post-surgery, these did not reach normality when compared to control participants (Adami et al., 1999). The results of the present study, identifying improvements in BA from baseline to month 4, with weak correlation to change in anthropometric measures suggest that these improvements may be a function of individual's perceptions of improved weight as opposed actual weight.

Fox (2000) also suggests that changes in PSW may be associated with the perception of improved fitness rather than actual changes. However, a study by Dionigi and Cannon (2009), examining perceived change in PSW in older adults following resistance training, suggests that a physiological effect, however small, precedes a change in PSW. Although correlational analysis cannot establish causation, the results of the present study, identify significant associations between changes in anthropometric measures and changes in PSPP constructs from month 8 to month 12. These results confirm those of Dionigi and Cannon (2009) and dispute the views put forward by Fox (2000) and Sonstroem (1997) that there is no relationship between changes in physiological status and changes in self-perception or

self-esteem. The present results indicate that physical self-perceptions are not purely based on psychological mechanisms, however as the physical self-perceptions did not change significantly over the time period further research is needed to substantiate the mechanisms that affect physical self-perceptions.

There are other plausible explanations for the lack of associations observed between changes in body composition and changes in physical self-perceptions during months 4-8. When examining physical self-perception improvements in participants following either a walking program or an abdominal electrical muscle stimulation (EMS) program, Andersen et al., (2006) identified significant improvements in PC only in the walking group. The authors suggested that the self-perceptions related to PC may have been more salient in the walking group, focusing on levels of physical condition, stamina and fitness, whereas the EMS group may have been more focused on body size changes as a consequence of the use of the EMS belt. As participants in the present study were following self-directed programs, their participation in different activities may have influenced the focus of their perceptions of the physical self.

In the same study Andersen et al. (2006) also found no significant improvements in BA in either group. However participants did improve significantly on a body dissatisfaction subscale. The authors provide explanation for these results highlighting the levels of specificity in the measures. For example, BA assesses perceptions of general body attractiveness whilst the dissatisfaction scale focuses on specific body areas. Monitoring changes in self-perceptions measures at each of the levels in the present study may have elicited interesting findings.

Overall, limited and weak strength correlations were observed between changes in anthropometric measures and changes in PSPP constructs during interim periods until month 8 to month 12 (Table 5.3). Similar moderate strength correlations were evident between changes in traditional

and alternative anthropometric measures and changes in BA. Change in %BF was the only traditional anthropometric measure to show a correlation with change in PC and PSW, demonstrating comparable strength correlations with those observed in $\Sigma 8SF$ and endomorphy. Thus H_3 is rejected, although the lack of significant change in physical self-perceptions over the time period limits the applicability of this finding and further research is needed, perhaps with additional waves of data, to further examine the relationship between changes in physical self-perceptions and changes in anthropometric measure over time in an overweight/obese population.

5.6.5 Limitations

Carr et al. (2007) identified that overweight, obese and morbidly obese individuals differ significantly from one another in terms of demographic and socioeconomic characteristics. The present study did not control for these characteristics, thus their influence on the relationship between body composition and physical self-perceptions cannot be accounted for. The study sample did however consist solely of Caucasians, thus limiting the possible influence of ethnicity on the relationship between body composition changes and physical self-perceptions. However, the sample also consisted of both male and female participants and it is recognised that there are gender differences in self-perceptions (Oehlof et al., 2009). Therefore this may have confounded research findings.

Additionally, no attempt was made to ascertain the degree of importance that participants placed on physical self-perceptions and the PSPP instrument that was administered includes only generic statements. This may have impacted the study findings as research suggests that perceived importance may have practical implications in physical self-perception research and generic instruments may not identify participants concerns over body specific areas (Shaw et al., 2000).

5.6.6 Future Directions

Perceptions of the physical self may be subject to a combination of anthropometric measures. Thus further analysis using hierarchical multiple regression analysis could examine the contributions of anthropometric measures to the PSPP constructs, in order to identify individuals most at risk of experiencing negative physical self-perceptions, so that interventions can be targeted effectively.

Furthermore, although research suggests no age effect on physical self-perceptions, it has been hypothesised that gender-specific consequences of obesity vary over the life course (Carr et al., 2007). Thus age may be an important predictor variable of the psychological effects of obesity in different genders, and is an area of research that may elicit interesting findings. Additional instruments, such as Fox and Corbins Perceived Importance Profile could also be utilised to examine the influence that this measure has on individuals' perceptions of the physical self.

The onset of obesity is another area that deserves attention within the psychological domain. Research indicates that the age of onset of obesity does not affect body satisfactions of obese individuals; however the durability of poor body image following weight loss may be influenced by the onset of obesity at an early age (Schwartz & Brownell, 2004). Further research on the relationship between body composition and PSPP constructs or other body image measures, may wish to examine the possible mediating effects of previous weight loss success/failure.

5.7 Conclusion

Findings from the present study suggest that high levels of fat, as identified by $\Sigma 8SF$, endomorphy and %BF are associated with low perceptions of PC, BA and PSW. High BMI and mass are also associated with low perceptions of BA. However, no differences in the strength of relationships between any

anthropometric variable and PSPP construct were observed. Thus H₅, that alternative anthropometric measures would show stronger correlation with PSPP constructs than traditional anthropometric measures with PSPP constructs, is rejected. All PSPP constructs showed significant improvement over time, thus H₆ is accepted. However changes in PSPP constructs showed, at best, weak correlations with traditional and alternative anthropometric measures. Therefore H₇ that changes in alternative anthropometric measures would show stronger correlation with changes in PSPP constructs than changes in traditional anthropometric measures and changes in PSPP constructs is rejected.

It is therefore concluded that as calculation of somatotype sub-components and $\sum 8SF$ requires considerable time and expertise, and the present results do not support a stronger association between changes in alternative anthropometric measures and physical self perceptions, compared to changes in traditional anthropometric measures and PSPP constructs, the use of these measures in physical self-perception research cannot be supported at this time. Furthermore, a more constructive approach to interventions that aim to reduce obesity may be to focus on health-related behaviours, such as increasing physical activity levels or improving diet, as opposed to focusing on reducing anthropometric measures that are known to be associated with low physical self-perceptions. This may also be useful in reducing the potential negative side-effects of weight loss interventions, such as increased concern about body image, by focusing on lifestyle factors that are within the participants' control and have a direct influence on participants' body weight and shape.

6. STUDY THREE: Anthropometric measures and metabolic syndrome

The work presented in Chapter Six aims to investigate possible relationship between changes in MetSyn parameters and associated changes in traditional and alternative anthropometric measures over a 6 month period. A review of pertinent research in the area of MetSyn is provided and evaluation of the methodological procedures and instrumentation considered. First relationships between traditional and alternative anthropometric measures with MetSyn parameters are examined. Secondly, the strength of the relationships are compared in order to identify whether alternative measures are stronger correlates of health status than traditional measures.

6.1 Introduction

The MetSyn is characterised by a clustering of inter-related risk factors including insulin resistance, abdominal obesity, increased serum triglycerides (TG), decreased high density lipoprotein cholesterol (HDL-C) and hypertension (Kukkonen-Harjula, 2005) (Table 2.6). The management of MetSyn depends primarily on modifying lifestyle, with a priority for weight reduction (Hall et al., 2006) and the effects of weight loss on MetSyn risk factors have been extensively studied. For example, the BP-lowering effect of weight loss has been documented in many clinical trials (He et al., 2000). In a meta-analysis of 25 randomised controlled trials (n=4874), Neter et al. (2003) identified a BP reduction of 4.4/3.6 mmHg for a 5-kg weight loss. This was by means of energy restriction, physical activity, or a combination of both treatment modalities. In the Trials of Hypertension Prevention, phase one (1992), 35-54year old overweight men and women with high-normal DBP were assigned to a weight loss intervention. After an 18-month follow-up period average weight loss of 3.9kg was associated with a 51% reduction in incidence of hypertension, systolic blood pressure (SBP) reducing by 2.9 mmHg, and diastolic blood pressure (DBP) reducing by 2.3 mmHg.

Weight loss has also been shown to lower total cholesterol (TC) and TG levels, and raise HDL-C (Liberopoulos et al., 2007). In a population of middle aged men following an exercise programme, Katznel (1997) reported 17% reductions in TG, 8% reductions in LDL-C, 11% increases in HDL-C and a 20% improvement in LDL/HDL ratio, following a significant weight loss of 8.1 ± 0.6 kg. Similar TG reductions of 15% were also reported by Tchernof et al. (2002), however this reduction was seen in association with a 14.5 ± 6.2 kg body weight loss, almost double that reported by Katznel (1997). Increases in HDL-C were also reported to be much higher in the study by Tchernof et al., (2002) study, reporting 60.6% increase in HDL-C concentrations.

The effect of weight loss is not restricted to improvements in blood lipids; it also has positive effects on blood glucose (BG) and insulin levels. Long et al., (1994) found that weight loss in patients with clinically severe obesity prevented the progression of impaired glucose tolerance to diabetes by more than 30-fold. Hamman et al. (2006) provide further support, examining the contribution of changes in weight, diet and physical activity on the risk of developing diabetes among patients who took part in intensive lifestyle modification. A total of 1,079 participants (mean BMI 33.9 kg.m^{-2} , mean body mass 94.1 kg) took part in the Diabetes Prevention Programme and a 16% reduction in diabetes risk was reported for every kilogram of weight lost, adjusted for changes in diet and activity. Katznel (1999) also reported 8% reductions in BG levels and 30% improvements in insulin responses following a significant weight loss of 8.1 ± 0.6 kg.

It is well known that the distribution of fat influences the prevalence of MetSyn for a given BMI (Byrne & Wild, 2007), and plays a key role in the pathophysiology of all facets of the MetSyn (Case et al., 2002). Furthermore, as documented in 2.3.2.2 there is some evidence of characteristic somatotypes being associated with disease and conditions such as CVD and dyslipidaemia (Carter & Heath, 2005), however, little is known about the association between MetSyn and somatotypes. Somatotype, a more holistic measure of one's body type, may have utility in evaluating an individuals'

metabolic risk, beyond their level of adiposity (Katzmarzyk et al., 2003). Therefore, the aim of Study Three was to evaluate the efficacy of using measures of physique (somatotype) as an indicator of health risk.

6.2. Aims and hypotheses

Identifying anthropometric measures that correlate with MetSyn markers may be helpful in both identifying individuals at risk and improve management of MetSyn. Therefore, the current study aimed to identify and examine the relationship between MetSyn risk factors (blood pressure, abdominal obesity (WC), HDL-C, fasting BG and TG levels) with both traditional and alternative anthropometric measures. The optimal monitoring interval for individuals with MetSyn is unknown, however recommendations suggest that fasting lipid profiles should be repeated at 3 to 6 months after initial assessments (National Heart, Lung & Blood Institute, 2001). Therefore, measurement of MetSyn markers and anthropometric profiling was conducted at baseline, and at 3 and 6 month intervals. The following alternative (experimental) hypotheses were formulated:

H₈) Baseline relationships between alternative anthropometric measures and MetSyn markers will be stronger than the relationship between traditional anthropometric measures and MetSyn markers.

H₉) Changes in alternative anthropometric measures will show a stronger correlation with changes in MetSyn markers than changes in traditional anthropometric measures and changes in MetSyn markers.

6.3 Methods

6.3.1 Study design and participants

Ethical approval for Study Three was received from the BioSciences Research Ethics Committee of the University of Portsmouth. The

fundamental design of this study was a prospective 6 month study, consisting of a cohort group, selected from Study One. Therefore no further recruitment and preliminary assessment was required. Please refer to Chapter 4.2.3 for details regarding recruitment processes, inclusion and exclusion criteria and preliminary screening methods.

Attempts were made to ensure all participants selected for the current study had been involved in Study One for no longer than 3 months, in order that previous changes would not impact the chances of significant changes being observed in the present study. Participants on antihypertensive medications or with pre-diagnosed diabetes were not eligible to participate in Study Three, however participants on cholesterol-lowering medications (n=3) were not excluded. Furthermore, those with pre-diagnosed diabetes were also excluded. An *a priori* power analysis indicated that a sample size of 30, with a *a priori* alpha level of 0.05 would yield a power of 0.9336. A total of 30 participants (n=7) and female (n=23) were recruited. Participant information sheets and consent forms are provided in Appendices 13 and 14.

6.4 Procedures

6.4.1 Anthropometric data collection

All anthropometric data were collected using the same protocol described in Chapter 3.1 and the data handling procedures described in Chapter 4.2 followed to allow calculation of BMI, WHR, %BF, $\sum 8SF$ and the three somatotype sub-components; endomorphy, mesomorphy and ectomorphy. Data were collected on 3 separate occasions; at baseline, 3 months following baseline, and 7 months following baseline. This resulted in all data collection periods being 3 months apart.

6.4.2 MetSyn data collection

After a period of rest, participants were seated and resting blood pressure (BP) recorded in duplicate and a mean value recorded, using either a Critical Care Unit (Minimon 7137B, Kontron, UK) or a portable monitor (HEM-755C, Omron, Sweden). A cuff suitable for 22-32cm arm girths was usually used, but a larger cuff size (32-42cms) was used when necessary.

In accordance with the University of Portsmouth's code of practice for taking of blood samples from human participants, TC, HDL-C, LDL-C, TG and BG were measured by obtaining a fingertip sample of capillary blood, using a SoftClix Pro (Accu-Chek, UK). Blood was collected in sodium heparinized plastic capillary tubes (EKF Diagnostic, UK) to prevent coagulation and blood droplets were then applied to a glucose panel test strip and lipid panel test strip (Polymer Technology Systems, USA). These strips were analysed using a glucose and cholesterol monitor (CardioChek PA, Polymer Technology Systems, USA).

Although TC and LDL-C are not related to the clinical diagnosis of metabolic syndrome the NCEP recommends that all individuals have a full lipid profile (Case et al., 2002) therefore these values were recorded. As stated by Wilson (2001) and Pottle (2007) TC and HDL levels can be measured at any time without the patient fasting. However when measuring BG, participants were required to fast for a period of 12 hours prior to the measurement being taken. Therefore all data were collected following an overnight fast. All data were collected according to the time scale described above in Chapter 6.4.1.

6.4.2.1 Use of CardioChek PA

The accuracy of a field method depends on the relationship between the patient's result and an accepted standard through a hierarchy of methods and materials (Myers et al., 2000). Because there is variability and system error in all commercial methods for determining lipid concentration,

determining the reference value can be difficult. The hierarchy of methods and materials for cholesterol is known as the National Reference System for Cholesterol (NRS/Chol) (Myers et al., 2000).

The Cholesterol Reference Method Laboratory Network (CRMLN) was established to certify manufacturers of clinical diagnostic products that measure TC, HDL-C and LDL-C (Bennett et al., 1992). The CRMLN (part of the Centres for Disease Control and Prevention (CDC)) has established test protocols using accepted 'gold standard' reference methods. Certification provides evidence of traceability to the NRS/Chol and in order to be CRMLN certified, results must meet the criteria detailed in Table 6.1.

Table 6.1. CRMLN cholesterol certification criteria, based on meeting recommendations from the National Cholesterol Education Programme (NCEP).

Parameter	TC	HDL-C	LDL-C
R ²	> 0.975	> 0.975	> 0.975
Bias at medical decision points	≤ 3% at 200mg.dL ⁻¹ (5.17mmol.L ⁻¹) ≤ 3% at 240mg.dL ⁻¹ (6.21mmol.L ⁻¹)	≤ 5% at 40mg.dL ⁻¹ (1.04mmol.L ⁻¹) ≤ 5% at 60mg.dL ⁻¹ (1.55mmol.L ⁻¹)	≤ 4% at 100mg.dL ⁻¹ (2.59mmol.L ⁻¹) ≤ 4% at 130mg.dL ⁻¹ (3.37mmol.L ⁻¹) ≤ 4% at 160mg.dL ⁻¹ (4.14mmol.L ⁻¹)
Accuracy*	≤ 3%	≤ 5%	≤ 4%
Precision**	≤ 3%	≤ 4%	≤ 4%

*calculated as: average % bias

**calculated as: among-run coefficient of variation

(Myers et al., 2000)

Whilst there are no specific criteria for acceptable performance, the National Cholesterol Education Programme (NCEP) of the National Institutes of Health (NIH) have established test protocols and guidelines for acceptable deviation from 'truth' (designed as the NRS/Chol reference value). These guidelines state that total error (TE) should be within certain limits from the reference values (Table 6.2).

Table 6.2. NCEP goals for lipids stated as total error.

	TC	HDL-C	LDL-C	TG
Total Error	$\leq 8.9\%$	$\leq 13.0\%$	$\leq 12.0\%$	$\leq 15.0\%$

*calculated as: total error = average % bias + (1.96 x among-run %CV)
(Warnick et al., 2002)

The CardioChek PA is a portable whole blood test system that uses reflectance photometry to determine three lipid concentrations on a single test strip; TC, HDL-C, TG (Panz et al., 2005). The system calculates low density lipoprotein cholesterol (LDL-C) levels using the Friedewald equation through the use of TC, HDL-C and TG levels (Polymer Technology Systems Inc, 2005). The clinical utility of the CardioChek PA has been tested and employed in a number of studies (Mendez-Gonazalez, 2008; Panz et al., 2005; Parikh et al., 2009). In a study of 41 participants the CRMLN certified that the CardioChek PA system met the required levels of accuracy and precision individually and the combined measure of total error as defined by the NCEP for TC and HDL-C. LDL-C, whilst showing excellent precision (Table 6.3) did not quite reach the certification criteria however shows excellent correlation to CRMLN criteria.

Whilst the CRMLN does not offer certification for triglycerides, clinical evaluation performed at three different geographic locations (n=111) demonstrated that CardioChek results compared favourably to results from an automated method run at CRMLN laboratory, identifying high accuracy ($R^2=0.97$) and precision (2.06% at 200mg.dL⁻¹ (2.26mmol.L⁻¹); 4.17% at 400mg.dL⁻¹ (4.52mmol.L⁻¹) (Polymer Technology Systems Inc, 2007). Furthermore, a study by Panz, et al. (2005) compared the precision and accuracy of the CardioChek PA to those analysed by the National Health Laboratory Service (NHLS), evaluating for conformance with NCEP guidelines. The authors concluded that, compared to NHLS methods, performance of the CardioChek PA system is acceptable, with NCEP guidelines met for all analyses at the two clinical cut-off points. It was noted however, that in the high range, TC and LDL-C results were under-estimated. The authors suggest that this could be attributed to their inclusion

of more samples with elevated lipid levels and that the ranges measurable by the analyses were limited. However, as the aim of the CardioChek PA is for screening, patients with levels outside these ranges would usually be referred for confirmatory measurements by a clinical diagnostic laboratory (Panz, et al., 2005).

Table 6.3. CardioChek PA System CRMLN and NCEP results for TC, HDL-C and LDL-C

Parameter	TC	Certification Criteria	Criterion Met
R ²	0.9804	> 0.975	✓
Bias at medical decision points	≤ 0.0% at 5.18mmol.L ⁻¹ ≤ 0.6% at 6.22mmol.L ⁻¹	≤ 3% at 5.18mmol.L ⁻¹ ≤ 3% at 6.22mmol.L ⁻¹	✓
Accuracy*	0.0%	≤ 3%	✓
Precision**	2.3%	≤ 3%	✓
Total error***	4.7%	≤ 8.9%	✓
Parameter	HDL-C	Certification Criteria	Criterion Met
R ²	0.98	> 0.975	✓
Bias at medical decision points	≤ 2.6% at 1.04mmol.L ⁻¹ ≤ 1.1% at 1.55mmol.L ⁻¹	≤ 5% at 1.04mmol.L ⁻¹ ≤ 5% at 1.55mmol.L ⁻¹	✓
Accuracy*	2.1%	≤ 5%	✓
Precision**	1.9%	≤ 4%	✓
Total error***	5.9%	≤ 13.0%	✓
Parameter	LDL-C	Certification Criteria	Criterion Met
R ²	0.96	> 0.975	x
Bias at medical decision points	≤ 2.6% at 1.04mmol.L ⁻¹ ≤ 1.1% at 1.55mmol.L ⁻¹	≤ 5% at 1.04mmol.L ⁻¹ ≤ 5% at 1.55mmol.L ⁻¹	✓
Accuracy*	0.1%	≤ 4%	✓
Precision**	2.6%	≤ 4%	✓
Total error***	5.3%	≤ 12.0%	✓

*calculated as: average % bias
 **calculated as: among-run CV
 *** calculated as: total error = accuracy + (1.96 x precision)
 (Polymer Technology Systems Inc, 2007).

A study by Giampietro et al. (2007) also evaluated the accuracy of the CardioChek PA analyser in comparison with diagnostic laboratory methods. TC measurement by CardioChek significantly correlated with laboratory determination ($r=0.79$) as did LDL-C. However, TG measurements were systematically under-estimated. Conversely, other studies indicate standardised methods consistent with CRMLN laboratory methods with high level of agreement for TC ($r=0.989$), HDL-C ($r=0.989$) and TG ($r=0.994$). The sample population in Giampietro et al (2007) study may have again influenced these results as the population screened consisted purely of individuals diagnosed with diabetes ($n=50$).

The lipid panel test strips used with the CardioChek PA have undergone Clinical Laboratory Improvement Amendments (CLIA) waived tests. This classification establishes that the lipid panel strips provide accurate, reliable and timely patient test results (Information on CLIA waivers, 2001). Interference testing with a wide variety of routinely occurring substances present in the blood has also demonstrated minimal interference with lipid panel test strip TC, HDL-C and TG results. Finally precision results testing two levels of whole blood, have demonstrated accurate and reliable results for TC, HDL-C and TG measurements with co-efficient of variations ranging from 4% to 6% (Table 6.4).

Table 6.4. Lipid panel precision testing.

		Whole Blood	
		Sample One	Sample Two
TC	No. of observations	20	20
	Mean concentration (mg.dL ⁻¹)	197.2 ± 8.4	251.3 ± 10
	Coefficient of variation (%)	4.3	4
HDL-C	No. of observations	20	20
	Mean concentration (mg.dL ⁻¹)	39.2 ± 2.5	61.5 ± 2.8
	Coefficient of variation (%)	6.4	4.6
TG	No. of observations	20	20
	Mean concentration (mg.dL ⁻¹)	157 ± 6.1	284 ± 16.8
	Coefficient of variation (%)	3.9	5.9

(Polymer Technology Systems Inc, 2003).

In conclusion the CardioChek PA system has documented traceability to the NRS/Chol and meets the NCEP performance criteria for accuracy and precision, offering a rapid, point-of-care method for the measurement of lipids (Panz et al., 2005).

6.4.3 Statistical analyses

6.4.3.1 Tests of normality

Evaluation of skewness and kurtosis revealed that TG ($z(\text{skew})=5.4$, and $z(\text{kurtosis})=10.3$) and DBP ($z(\text{skew})=5.2$, and $z(\text{kurtosis})=7.3$) were not normal. Furthermore, Kolmogorov-Smirnov's test showed that both TG and HDL-C were not normally distributed ($D(26)=0.334$, $P<0.05$, and $D(26)=0.193$, $P<0.05$, respectively). Natural logarithmic transformation was conducted on TG, and HDL-C however this only improved the distribution of HDL-C. Therefore, untransformed variables are presented for TG with transformed variables reported for HDL-C.

6.4.3.2 Tests of difference

Differences in individual MetSyn components between individuals with and without MetSyn at baseline were evaluated using multivariate analysis of variance. Somatotype category and change in global somatotype was analysed using the procedures described in Chapter 3.3. Analysis of variance for repeated measures with Bonferroni adjustment was used to investigate the change from baseline, mid measurement and final measurement of anthropometric measures and MetSyn components. Mauchly's test indicated that the assumption of sphericity had been violated for LDL-C and BG ($X^2(2) = 0.761$, $P<0.05$, and $X^2(2) = 0.615$, $P<0.05$, respectively). Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon=0.807$ and $\epsilon=0.722$).

6.4.3.3 Correlation analysis

A Pearson's Correlation Coefficient was used to examine the correlation of components of the MetSyn at baseline with anthropometric measures at baseline. Change was calculated from baseline to final measurement session and normality checks repeated for these change variables. All change variables (anthropometric and MetSyn) were normally distributed, even when single measures were non normal. A Pearson's Correlation Coefficient was used to calculate the correlation of change in components of MetSyn with changes in anthropometric variables.

6.5 Results

Data are presented for 26 participants who attended all measurement sessions. Three participants dropped out after the initial measurement session and one did not attend the final measurement session. Baseline demographic, traditional and alternative anthropometric measures are provided in Table 6.5, including breakdown by gender and BMI classification. The most widely used NCEP-ATP III criteria for MetSyn (Han & Lean, 2006), were used to determine the presence of the MetSyn (Table 2.8).

6.5.1 Prevalence and baseline characteristics

At baseline 16 of the 26 participants were classified as endomorphic-mesomorphs, 8 as mesomorph-endomorphs and 2 as mesomorphic-endomorphs. Fourteen participants had at least three of the five defining criteria and were classified as having MetSyn (Fig. 6.1). At completion 50% of those MetSyn cases had resolved.

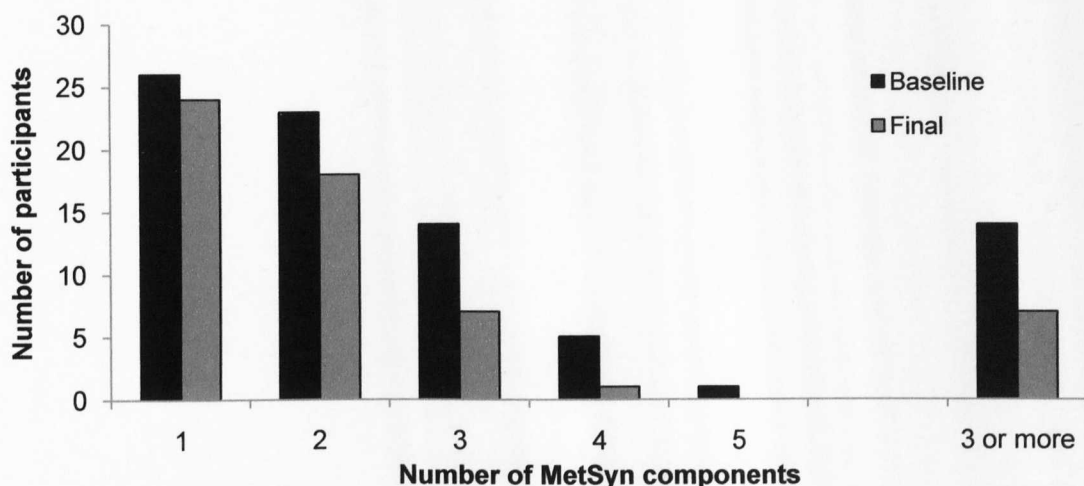


Figure 6.1. Number of simultaneous abnormalities observed amongst all participants at baseline and at final measurement (n=26)

The number of individual metabolic abnormalities observed amongst the participants are shown in Figure 6.2. Raised TG was the least prevalent MetSyn component, evident in only 4 of the 26 participants. Low HDL-C and increased WC (abdominal obesity) were the most prevalent risk factors affecting 22 and 23 of the 26 participants, respectively. Of the 14 participants meeting the clinical criteria for the diagnosis of MetSyn (3 or more risk factors) all participants fulfilled the criterion for abdominal obesity and high blood pressure (Fig. 6.2) In individuals presenting with 3 risk factors the leading combination included abdominal obesity, high blood pressure and low HDL-C. In individuals presenting with 4 risk factors the leading combination included abdominal obesity, high blood pressure, low HDL-C and raised TG (Fig. 6.2).

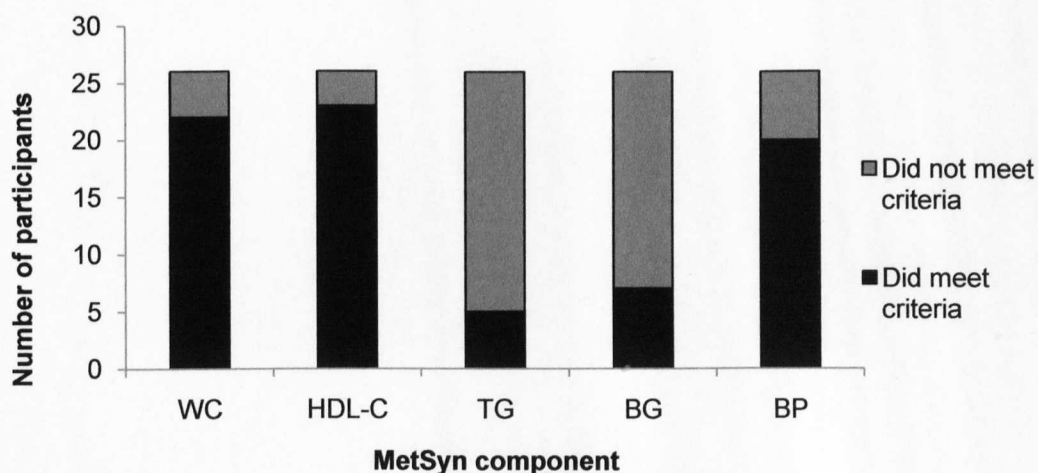


Figure 6.2. Number of individual metabolic abnormalities observed amongst all participants (n=26).

Table 6.5. Mean (\pm SD) baseline demographic and body composition measures for all participants who completed Study Three (n=26), including breakdown by gender and BMI classification.

	Male (n=6)	Female (n=20)	Overweight (n=8)	Obese (n=13)	Morbidly Obese (n=5)	All (n=26)
Age (years)	47.9 \pm 18.0	43.4 \pm 17.4	42.8 \pm 16.5	47.8 \pm 18.2	39.4 \pm 20.1	44.7 \pm 17.7
Height (cm)	175.8 \pm 8.3	162.3 \pm 7.3	168.3 \pm 6.4	162.2 \pm 9.3	169.8 \pm 13.3	165.5 \pm 9.7
Mass (kg)	97.8 \pm 18.7	85.4 \pm 15.8	78.6 \pm 6.5	84.7 \pm 11.3	113 \pm 20.3	88.3 \pm 14.4
BMI (kg.m ⁻²)	31.2 \pm 4.0	33.2 \pm 6.3	27.7 \pm 1.4	32.1 \pm 1.3	39.3 \pm 7.1	32.1 \pm 5.0
WHR	1.0 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 \pm 0.1
BF (%)	26.1 \pm 5.7	36.0 \pm 3.5	30.3 \pm 6.7	33.6 \pm 4.3	39.7 \pm 3.4	33.2 \pm 5.0
Σ 8SF (mm)	132.4 \pm 50.0	202.4 \pm 46.0	153.4 \pm 40.1	177.6 \pm 40.8	261.2 \pm 42.3	186.2 \pm 55.8
Endomorphy	4.6 \pm 1.1	6.8 \pm 1.0	5.3 \pm 1.4	6.3 \pm 1.0	7.7 \pm 1.0	6.3 \pm 1.4
Mesomorphy	6.4 \pm 1.0	7.5 \pm 1.5	6.0 \pm 0.9	7.4 \pm 0.7	8.7 \pm 2.2	7.2 \pm 1.5
Ectomorphy	0.5 \pm 0.6	0.2 \pm 0.2	0.6 \pm 0.5	0.1 \pm 0.0	0.1 \pm 0.0	0.3 \pm 0.3

Baseline demographic data were collected for all participants and are displayed in Table 6.6. Individuals with MetSyn had significant differences in baseline BMI ($35.4 \pm 6.5 \text{ kg.m}^{-2}$ vs. $29.32.4 \pm \text{kg.m}^{-2}$), body mass ($94.8 \pm 20.5 \text{ kg}$ vs. $80.7 \pm 8.1 \text{ kg}$) blood pressure (systolic; $142 \pm 14 \text{ mmHg}$ vs. $122 \pm 18 \text{ mmHg}$, and diastolic; $82 \pm 13 \text{ mmHg}$ vs. $73 \pm 7.0 \text{ mmHg}$), and triglycerides ($1.56 \pm 1.20 \text{ mmol.L}^{-1}$ vs. $0.67 \pm 0.20 \text{ mmol.L}^{-1}$), compared with individuals without MetSyn. Both groups were of similar age and had similar baseline levels of blood glucose. Men with MetSyn had significant differences in HDL-C compared with men without MetSyn ($0.48 \pm 0.16 \text{ mmol.L}^{-1}$ vs. $0.98 \pm 0.39 \text{ mmol.L}^{-1}$). Irrespective of MetSyn status all women displayed similar HDL-C and LDL-C levels. Waist circumference in both men and women significantly differed between those with and without MetSyn ($117.9 \pm 6.0 \text{ cm}$ vs. $97.2 \pm 2.1 \text{ cm}$ for males and $108.5 \pm 18.0 \text{ cm}$ vs. $90.3 \pm 6.7 \text{ cm}$ for women).

Table 6.6. Mean (\pm SD) metabolic and haemotological baseline characteristics of individuals with and without metabolic syndrome (n=26).

	With Met Syn	Without Met Syn	P
Number of participants	14	12	-
Men (n) (%)	3 (50%)	3 (50%)	0.93
Female (n) (%)	11 (55%)	9 (45%)	0.93
Age (years)	45.7 ± 17.2	43.2 ± 18.2	0.72
BMI (kg.m^{-2})	35.4 ± 6.5	29.3 ± 2.4	<0.00*
Mass (kg)	94.8 ± 20.5	80.7 ± 8.1	0.04*
TC (mmol.L^{-1})	4.86 ± 1.75	4.73 ± 1.32	0.84
HDL-C in men (mmol.L^{-1})	0.48 ± 0.16	0.98 ± 0.39	0.01*
HDL-C in women (mmol.L^{-1})	0.86 ± 0.53	1.16 ± 0.75	0.31
LDL-C (mmol.L^{-1})	3.42 ± 1.77	3.32 ± 1.52	0.88
TG (mmol.L^{-1})	1.56 ± 1.25	0.67 ± 0.20	0.02*
BG (mmol.L^{-1})	5.22 ± 0.83	5.83 ± 1.02	0.11
WC in men (cm)	117.9 ± 6.0	97.2 ± 2.1	0.04*
WC in women (cm)	108.5 ± 18.0	90.3 ± 6.7	0.01*
SBP (mmHg)	142 ± 14	122 ± 18	<0.00*
DBP (mmHg)	82 ± 13	73 ± 7	0.04*

Values are mean \pm SD except as noted.
 *significant difference between participants with and without MetSyn at 0.05 level

6.5.2 Baseline relationships between anthropometric measures and MetSyn components in all individuals

At baseline BMI, mass and WHR all showed significant correlation with WC, SBP and DBP (Table 6.7). BMI showed the strongest correlation with WC ($r(24)=0.89, P<0.05$) and WHR the strongest relationship with both SBP and DBP; ($r(24)=0.67, P<0.05$). Low to moderate relationships were also seen between BMI and TG; ($r(24)=0.38, P<0.05$) and mass and HDL-C; ($r(24)=-0.38, P<0.05$). %BF showed no significant correlation with any Met Syn marker. $\Sigma 8SF$, endomorphy and mesomorphy all showed significant correlation with WC, with the strongest relationship observed with mesomorphy ($r(24)=0.73, P<0.05$). Ectomorphy was the only anthropometric measure to correlate with BG ($r(24)=0.42, P<0.05$) and mesomorphy the only alternative anthropometric measure to show correlation with SBP and DBP. Mesomorphy also showed a significant moderate correlation with TG ($r(24)=0.44, P<0.05$).

Table 6.7. Relationship (Pearson's correlation coefficient) of traditional and alternative anthropometric indices with components of the metabolic syndrome at baseline in all individuals (n=26).

	Log-HDL-C	TG	BG	WC	SBP	DBP
TRADITIONAL						
BMI	-0.38	0.38*	-0.26	0.89*	0.59*	0.58*
Mass	-0.38*	0.23	-0.24	0.81*	0.56*	0.53*
WHR	-0.34	0.38	0.25	0.78*	0.67*	0.67*
BF	-0.11	0.18	-0.07	0.25	-0.17	-0.22
ALTERNATIVE						
$\Sigma 8SF$	-0.27	0.20	-0.08	0.54*	0.34	0.14
Endomorphy	-0.28	0.25	-0.05	0.49*	0.10	0.05
Mesomorphy	-0.28	0.44*	0.27	0.73*	0.50*	0.51*
Ectomorphy	0.44	-0.23	0.42*	-0.29	0.05	0.04

* $P<0.05$

6.5.3 Change in anthropometric measures and MetSyn components

6.5.3.1 Individuals with MetSyn

In individuals with MetSyn, collectively all MetSyn components changed significantly over time ($F=4.392_{,16,38}$, $P<0.05$, $\text{Eta}^2=0.65$, $1-\beta=0.999$). Univariate analysis revealed that significant changes were apparent in BG, HDL-C, SBP and DBP ($F=12.204$, $P<0.05$, $\text{Eta}^2=0.484$, $1-\beta=0.991$; $F=4.682$, $P<0.05$, $\text{Eta}^2=0.171$, $1-\beta=0.359$; $F=3.495$, $P<0.05$, $\text{Eta}^2=0.212$, $1-\beta=0.601$; and $F=6.892$, $P<0.05$, $\text{Eta}^2=0.346$, $1-\beta=0.890$, respectively).

TG showed no significant change over time (Fig. 6.3). BG reduced significantly from baseline to mid measurement ($0.9\pm0.3\text{mmol.L}^{-1}$) and baseline to final measurement ($1.1\pm0.3\text{mmol.L}^{-1}$), however between the mid measurement and final stage no significant change was observed. HDL-C showed a significant increase of $0.2\pm0.1\text{mmol.L}^{-1}$ from baseline to final measurement. SBP also showed a significant overall reduction of $6\pm3\text{mmHg}$ from baseline to final measurement stage. Significant change was observed in DBP from baseline to final measurement stage ($6\pm2\text{mmHg}$) and a significant reduction of $5\pm2\text{mmHg}$ from mid measurement to final stage.

In individuals with MetSyn the only traditional anthropometric variable that showed significant change over time was %BF ($F=8.606$, $P<0.05$, $\text{Eta}^2=0.398$, $1-\beta=0.948$), showing an overall reduction of $1.6\pm0.6\%$ (Fig.6.4). $\Sigma 8\text{SF}$ and endomorphy also showed statistically significant change ($F=10.323$, $P<0.05$, $\text{Eta}^2=0.443$, $1-\beta=0.907$ and $F=12.159$, $P<0.05$, $\text{Eta}^2=0.483$, $1-\beta=0.933$). Both variables showed significant reductions between all stages (Fig.6.5). For example $\Sigma 8\text{SF}$ showed significant reduction of $9\pm3\text{mm}$ and $13\pm4\text{mm}$ between baseline and mid stage, and mid stage and final stage respectively. Endomorphy showed a significant reduction of 0.6 ± 0.1 from baseline to final stage.

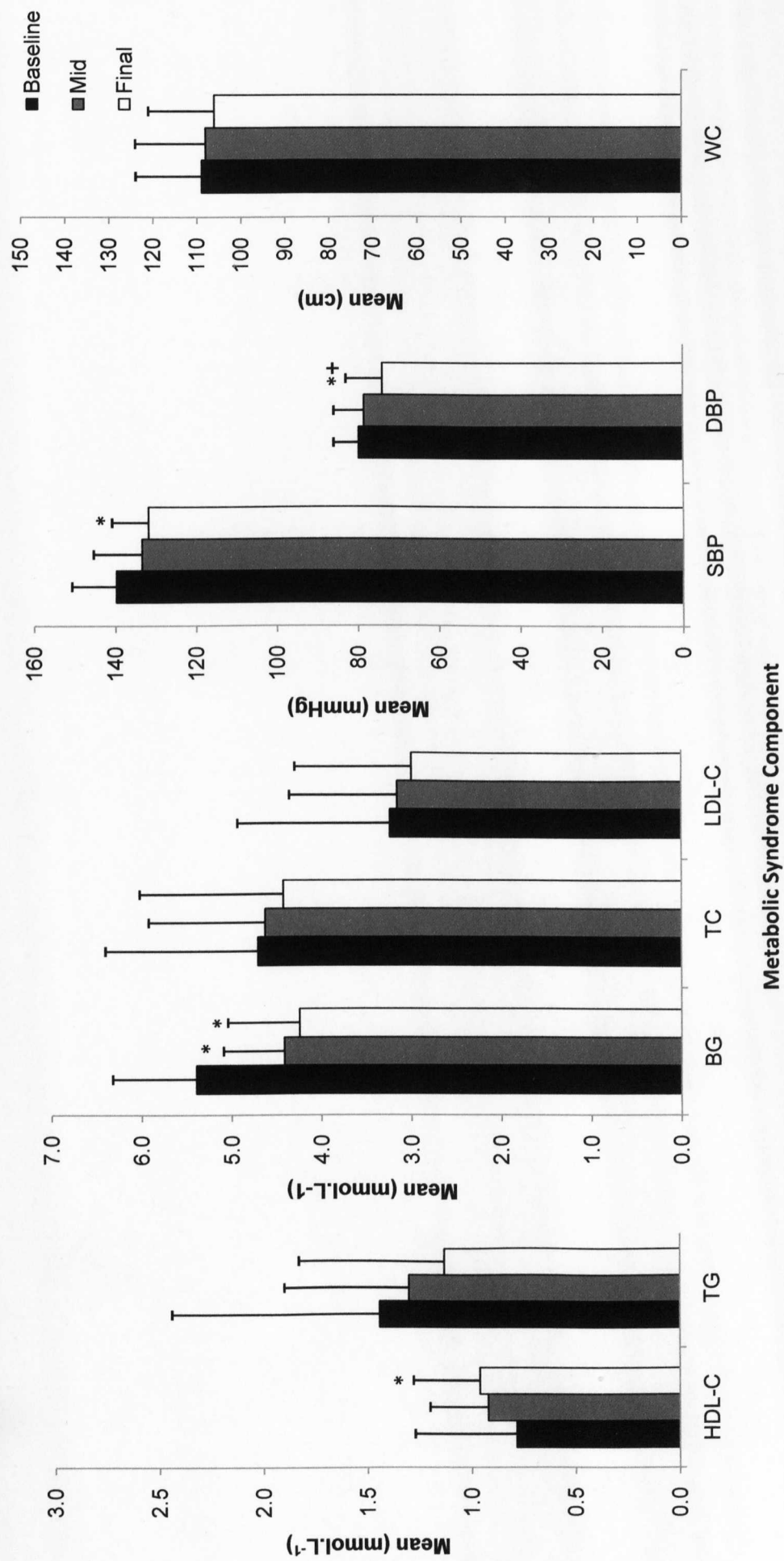


Figure 6.3. Metabolic and haematological mean scores of participants with MetSyn (n=14) at baseline, mid and final measurement sessions

*P<0.05 compared with baseline

†P<0.05 compared with mid

Vertical bars show standard errors of the mean

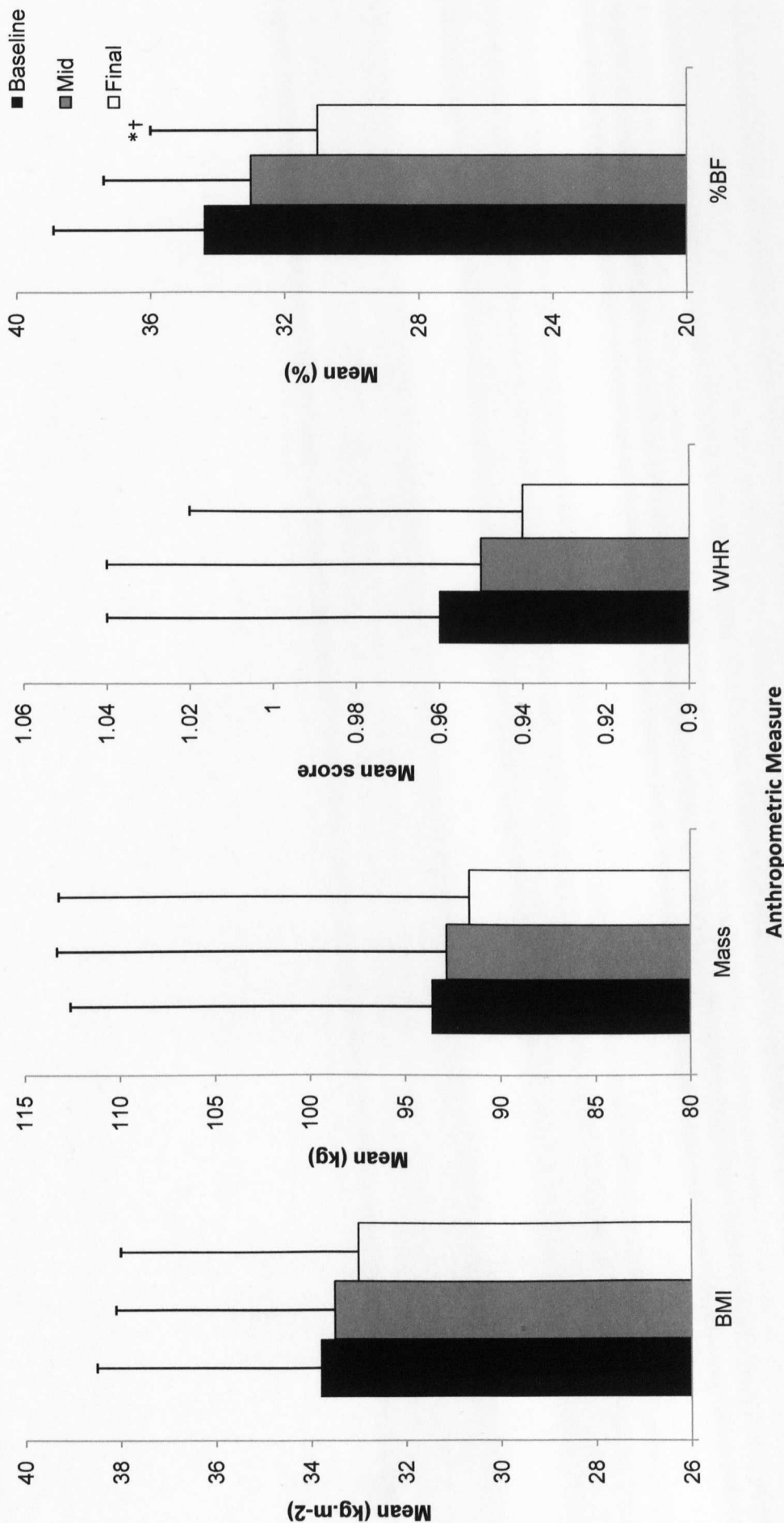


Figure 6.4. Mean scores for traditional anthropometric measures of individuals with Met Syn (n=14) at baseline, mid and final measurement sessions
 *p<0.05 compared with baseline
 †p>0.05 compared with mid

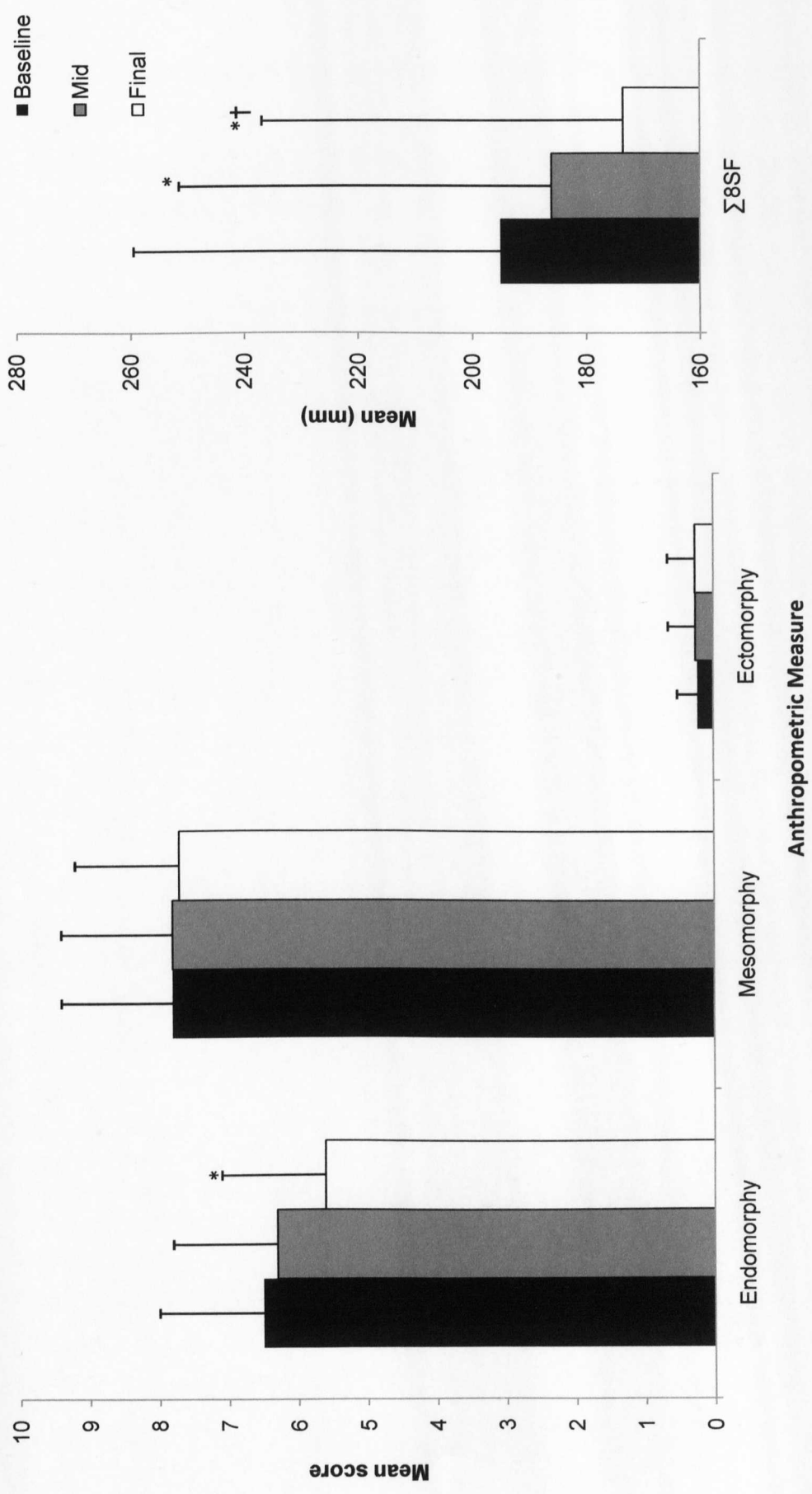


Figure 6.5. Mean scores for alternative anthropometric measures of individuals with Met Syn (n=14) at baseline, mid and final measurement sessions

*P<0.05 compared with baseline

†P>0.05 compared with mid

6.5.3.2 All individuals (with and without MetSyn)

When examining change in all individuals (with and without MetSyn), a significant change in global somatotype was observed ($F=38.033_{,2,25}, P<0.05, \text{Eta}^2=0.60, 1-\beta=1.00$). The mean somatoplots in Figure 6.6 reflect this difference as they move from left to right across the somatochart.

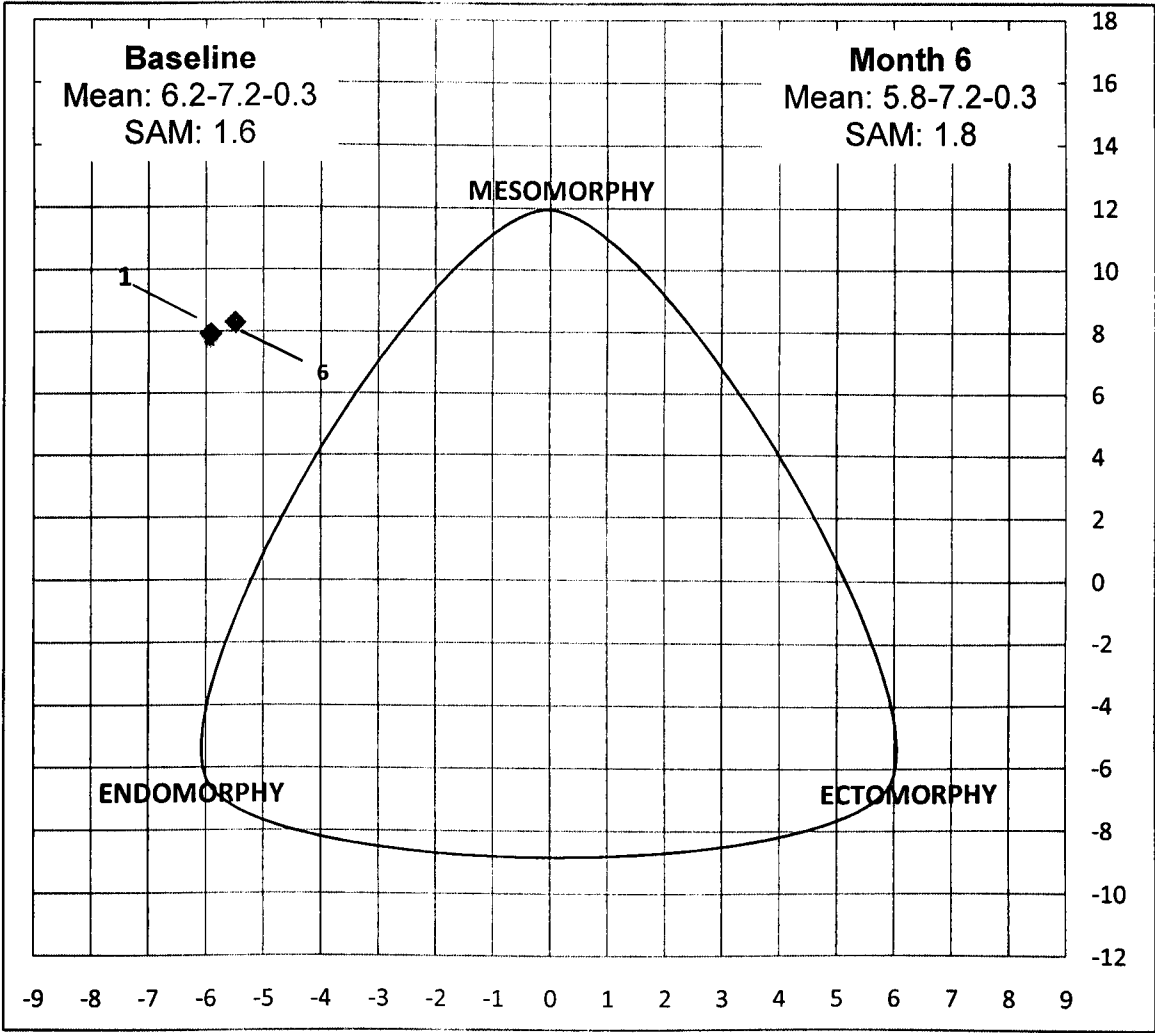


Figure 6.6. Mean somatotype (n=26) for baseline to month 6
 \bar{S} = mean somatotype, SAM = somatotype attitudinal mean

Univariate analysis revealed that mass showed a significant reduction from $88.3\pm17.4\text{kg}$ at baseline to $86.4\pm17.8\text{kg}$ at final measurement ($F=4.850_{,2,25}, P<0.05, \text{Eta}^2=0.162, 1-\beta=0.777$). %BF also showed a significant reduction of $1.5\pm0.5\%$ ($F=10.811_{,2,25}, P<0.05, \text{Eta}^2=0.302, 1-\beta=0.959$). $\Sigma 8\text{SF}$ and

endomorphs were the only alternative anthropometric variables that showed significant change over time ($F=15.882$, $_{2,25}$, $P<0.05$, $\text{Eta}^2=0.388$, $1-\beta=0.999$ and $F=7.002$, $_{2,25}$, $P<0.05$, $\text{Eta}^2=0.219$, $1-\beta=0.758$). $\Sigma 8\text{SF}$ was the only variable that showed significant reduction at every stage, reducing from $186\pm 56\text{mm}$ at baseline to $175\pm 57\text{mm}$ at mid stage, with a further reduction to $166\pm 57\text{mm}$ at the final stage. Endomorphy decreased from 6.3 ± 1.4 to 5.5 ± 1.8 from baseline to final measurement. When examining change in all individuals (with and without MetSyn), BG was the only MetSyn component to show significant change over time, reducing by $1.4\pm 0.2\text{mmol.L}^{-1}$ ($F=25.389$, $_{2,25}$, $P<0.05$, $\text{Eta}^2=0.504$, $1-\beta=1.00$).

6.5.4 Relationship between changes in anthropometric measures and changes in Met Syn components in individuals with Met Syn.

Change in WC showed strong significant correlations with change in all traditional and alternative anthropometric measures, with the exception of ectomorphy (Table 6.8). Change in mesomorphy also showed a significant moderate inverse relationship with change in DBP ($r(12)=0.61$, $P<0.05$). Change in all other MetSyn components did not correlate with change in any anthropometric measures (Table 6.8).

Table 6.8. Relationship of change in anthropometric variables (pre and post) with change in components of the MetSyn in individuals with MetSyn (n=14)

	HDL-C	TG	BG	WC	SBP	DBP
TRADITIONAL						
BMI	-0.50	0.30	0.06	0.89*	0.20	-0.33
Mass	-0.49	0.13	-0.04	0.82*	0.25	-0.35
WHR	-0.35	0.26	0.03	0.81*	0.25	-0.16
BF	-0.50	0.30	0.06	0.89*	0.20	-0.33
ALTERNATIVE						
$\Sigma 8\text{SF}$	-0.49	0.22	0.04	0.83*	0.17	-0.18
Endomorphy	-0.45	0.23	0.18	0.89*	0.17	-0.43
Mesomorphy	-0.07	-0.01	0.43	0.61*	0.24	-0.61*
Ectomorphy	-0.10	0.17	-0.11	0.12	-0.23	-0.31

* $P<0.05$

6.5.5 Relationship between changes in anthropometric measures and changes in Met Syn components in all individuals (with and without MetSyn)

When examining the relationship between changes in anthropometric measures and changes in MetSyn components among all individuals (with and without MetSyn) the number of correlations increased (Table 6.9). HDL-C, BG, WC, SBP and DBP also showed improvements (increase in HDL-C and decrease in other components) that correlated with reductions in BMI, mass and WHR. For example, HDL-C increases as BMI, mass and WHR decreased ($r(24)=0.46, P<0.05$, $r(24)=0.45, P<0.05$, and $r(24)=0.48, P<0.05$), respectively. %BF was the only anthropometric measure to correlate with TG, showing a significant moderate association ($r(24)=0.50, P<0.05$). Additionally, reduction in $\Sigma 8SF$ from baseline to final measurement showed a significant correlation with a reduction in WC ($r(24)=0.43, P<0.05$) and DBP ($r(24)=0.41, P<0.05$). Change in mesomorphy also showed significant correlation with HDL-C, BG and WC ($r(24)=0.40, P<0.05$).

Table 6.9. Relationship of change in anthropometric variables (pre and post) with change in components of the metabolic syndrome in all individuals (n=26)

	HDL-C	TG	BG	WC	SBP	DBP
TRADITIONAL						
BMI	0.46*	0.30	0.42*	0.48*	0.45*	0.47*
Mass	0.45*	0.30	0.42*	0.48*	0.45*	0.47*
WHR	0.48*	0.30	0.42*	0.50*	0.48*	0.50*
%BF	-0.29	0.50*	0.22	0.73*	-0.07	-0.06
ALTERNATIVE						
$\Sigma 8SF$	0.34	0.32	0.37	0.43*	0.37	0.41*
Endomorphy	0.30	0.23	0.37	0.38	0.32	0.34
Mesomorphy	0.40*	0.18	0.40*	0.40*	0.37	0.38
Ectomorphy	-0.13	-0.12	-0.30	-0.05	-0.02	0.04

* $P<0.05$

6.6 Discussion

6.6.1 Prevalence and baseline characteristics

The MetSyn has become one of the major public health challenges around the world (Fulop et al., 2006; Grundy, 2003) and there has been growing interest in this constellation of closely related cardiovascular risk factors (Alberti et al., 2005). In the present study the prevalence of MetSyn, defined in accordance with NCEP-ATP III criteria was 54% (Fig. 6.1). All 26 individuals in the study had at least one of the risk factors of the MetSyn, in addition to obesity, and 20% had four or more (Fig. 6.2). Using ATP III criteria, data derived from the NHANES III identified a 23.7% age-adjusted prevalence of MetSyn in a population of 8814 men and women >20years (Ford et al., 2002). Comparable prevalence data (24.4%) were observed in a study of 14,719 women, aged <45years, (Ridker et al., 2003), with an age and sex-adjusted prevalence of 24% seen in 3224 Caucasian participants from the Framingham Offspring Study (Meigs et al., 2003).

In the present study the leading combination of risk factors in individuals presenting with MetSyn included abdominal obesity, high blood pressure and low HDL-C. This concurs with results of NHANES III data which found that abnormal blood pressure or HDL-C occurred in almost 39% and 43% of individuals with BMI $\geq 30 \text{ kg.m}^{-2}$ (Case et al., 2002). Raised TG was the least prevalent MetSyn component observed (4 out of 26 participants reaching clinical criteria $>110/\text{mg.dL}^{-1}$). This is similar to results obtained by Sartorio et al., (2007) where the lowest prevalence MetSyn component was TG (28%). Case et al., (2002), identified that neither TC, nor LDL-C were significantly different between participants with or without MetSyn. The results of the present study also identify non-significant differences in TC and LDL-C, thus the NCEP recommendation that all individuals should undergo a full lipid profile (i.e. TC, HDL-C, LDL-C and TG) seems justified.

In contrast to TC and LDL-C, the present study identified significant differences in baseline BMI, body mass, WC, TG and BP between individuals with and without MetSyn. Obesity has been described as the central causative component in the development of the MetSyn (Fulop et al., 2006) thus it is not surprising that the individuals in the present study had higher BMI and body mass values than those without MetSyn. Furthermore, the first feature of the MetSyn to appear in most individuals is abdominal obesity (Byrne & Wild, 2007) and it is well documented that abdominal fat distribution predisposes individuals to metabolic disorders such as glucose intolerance, hypertension and dyslipidaemia (Cigolini et al., 1995). Therefore, the significantly higher values of WC seen in individuals with MetSyn (males 117.9 ± 6.0 cm, females 108.5 ± 18.0 cm) compared to those without MetSyn (males 97.2 ± 2.1 cm, female 90.3 ± 6.7 cm) are to be expected.

Both former and current smoking has been associated with an increased incidence of MetSyn with odds ratios of 1.66 ($P < 0.0001$) and 2.38 ($P < 0.0001$), respectively (Ishizuka et al., 2005). Pangiatakas et al. (2004) identified an association between tobacco smoke and dyslipidemia and Masulli et al. (2006) reported similar findings in a large population-based sample of 2412 non-diabetic men, aged 35-65 years. However, Masulli et al. (2006) identified that other components of MetSyn, such as hypertension and hyperglycemia, were less common in smokers. This suggests that a higher prevalence of dyslipidemia (reduced HDL-C and high TG) is the main contributing factor to the increased prevalence of the MetSyn in smokers. Whilst it is noted that both studies used cross-section observational data, thus precluding inferences of a causal relationship, it is acknowledged that a small proportion of the current study sample were classified as former smokers ($n=3$) and recent quitters ($n=2$), thus may have confounded results.

6.6.2 Baseline relationships between anthropometric measures and MetSyn components in all individuals

The main aim of the present study was to verify the relationship between MetSyn components and anthropometric indices and identify whether changes in anthropometrical measures correlate with changes in MetSyn components. At baseline, in all individuals, all metabolic and haematological measures were statistically significantly related to at least one anthropometric measure (Table 6.7). Moderate significant correlations were observed between the traditional anthropometric variables; BMI, mass and WHR, with the MetSyn component WC. This relationship was strongest in BMI and mass. These results are in agreement with much research evidence that identifies that BMI and mass correlate closely with WC (Lean et al., 1995; Zhu et al., 2002), with lower correlations observed between WHR and WC (Vazquez et al., 2007).

The somatotype components endomorphy and mesomorphy were also statistically significantly correlated with WC (Table 6.7) although the strength of the relationship was lower in endomorphy ($r=0.49$), compared with the weight-related parameters of BMI and mass ($r=0.80$ and 0.81 , respectively). A similar strength of relationship was observed between mesomorphy and WC ($r=0.73$) and WHR and WC ($r=0.78$). When classifying men ($n=824$) photoscopically into obesity status, and then into android (central) and gynoid (generalized) classes of body fat patterning, Mueller and Joos (1985) found that android obese men were significantly more mesomorphic and less endomorphic than the gynoid obese ($P < 0.01$), indicating an association between abdominal obesity and mesomorphy. This could be explained by the use of the Sheldonian somatotype where estimates of endomorphy and mesomorphy relate to the development of the upper (thorax) vs lower (abdomen) trunk, respectively (Carter & Heath, 2005). However, the present study also identified a relationship between mesomorphy and abdominal obesity (as measured by WC) using the Heath-Carter method that does not include any measurements from the trunk to estimate mesomorphy. A

possible explanation for the association observed in the present study may be due to the analysis of mesomorphy as an individual measure, without accounting for the confounding inter-relationship among the somatotype components.

Risk estimates based on population studies indicate that obesity, in particular central obesity, can be directly attributed to at least two-thirds of the prevalence of hypertension (Narkiewicz, 2006). Furthermore hypertension is around six times more frequent in obese participants than in lean men and women (Poierier & Rheume, 2009). In the present study, BMI, mass and WHR were significantly related to SBP and DBP providing further support of the relationship between obesity, and blood pressure (Table 6.7). Conversely, whilst a high endomorphy rating has been associated with hypertension in adults (Makgae et al., 2007), no correlation between endomorphy and blood pressure was evident in the present study. This is in contrast to other research that has suggested that endomorphy can be considered a general indicator of the predisposition to various chronic diseases (Buffa et al., 2007). Mesomorphy however, showed moderate relationships ($r=0.50$) with both SBP and DBP in the present study (Table 6.7). These results agree in part with those of Kalichman et al. (2004) who examined the relationship between BP and components of somatotype using the methods of Heath and Carter and found individuals with high endomorphy and mesomorphy displayed high mean values of SBP and DBP. When examining the relationship between somatotype and coronary heart disease risk factors however, Malina et al., (1997) note that it may be high endomorphy and high mesomorphy that may be the predisposing combination of components for disease risk factors rather than either one separately. Mass was the only anthropometric variable to show significant correlation with HDL ($r(24)= -0.38$, $P<0.05$), which is in agreement with findings of Chrzanowska et al. (2006). Furthermore, similar results to Chrzanowska et al., (2006) were seen in the present study with high levels of mesomorphy significantly associated with low levels of TG.

6.6.3 Relationship between changes in anthropometric measures and changes in Met Syn components

6.6.3.1 Individuals with MetSyn

Abdominal obesity, as measured by WC, was the MetSyn component that displayed the strongest and greatest number of correlations with anthropometric variables at baseline in the present study (Table 6.8). When examining the relationship of change in anthropometric variables with change in components of the MetSyn, WC and DBP were the only MetSyn components that produced significant associations (Table 6.8). A possible explanation may be due to the small participants numbers as only half of the participants were diagnosed with MetSyn, reducing the numbers to 14. There are marked differences in how abdominal obesity is defined as a component of MetSyn (Sartorio, 2007), although it has become a prerequisite for MetSyn in the newer definitions, such as the IDF and NCEP ATP III criteria. The results of the present study re-affirm the importance of abdominal obesity in the diagnosis of MetSyn.

A strong significant relationship was seen between change in WC and change in WHR (Table 6.8). Whilst WHR is an accepted index of fat distribution, its use to assess changes in fat distribution is questionable (Van der Kooy et al., 1993). The use of WHR may not be appropriate to assess obesity and related health risk because it has statistical limitations (Allison et al., 1995), is highly age dependent and relationships that may be present with separate circumference measurements may be obscured when adjusted to a ratio (Goran et al., 1995). For example, as identified by Seidell et al. (2001) a narrow waist and large hip circumference may both protect against CVD, however these specific effects of each girth measure are poorly captured in the waist-to-hip ratio. Furthermore an individual with enlarged waist and hip girths can have a 'healthy' WHR, despite the presence of excess abdominal adipose tissue. WHR is also less sensitive to weight gain/loss (Vazquez et al., 2007). Indeed when examining individuals with

MetSyn in the present study, WHR did not show significant change over time (Fig.6.4). Thus whilst the change in WHR and the change in WC are significantly correlated, neither showed significant change over time.

Change in BMI and mass also showed significant strong correlation with change in WC in the present study, although again these measures did not show significant change over time. In a study of 2635 participants investigating the correlation between changes in body weight and body composition parameters, a significant decrease in body weight of 3kg over one year corresponded to a significant decrease of almost 3cm in WC (Miyatake et al., 2007). Although the changes in the present study are much smaller, the association is still apparent. Furthermore, the relationship between weight loss and reduction in WC in the present study ($r=0.89$) is similar to that obtained by Han et al., (1997) over the same time period ($r=0.68$). It is again worth noting that whilst BMI and mass reduced over time, these changes were not significant.

In individuals with MetSyn there were significant improvements in HDL-C, BG, SBP and DBP (Fig. 6.3). Whilst these did not correlate with significant weight loss, the incidence of MetSyn among these participants reduced by half. Excess adiposity is thought to play a key role in the pathophysiology of all facets of the MetSyn (Case et al., 2002) therefore the significant changes observed in endomorphy and $\sum 8SF$ may have contributed to these improvements. However, with no correlation evident between the change in these anthropometric variables and the change in MetSyn components their utility, from a health perspective, is limited.

It has been suggested that whilst it is the combination of MetSyn components as opposed to a single component that increases cardiovascular risk (Bosello & Zamboni, 2003), not all individuals display a clustering of metabolic and cardiovascular risk factors (Karelis et al., 2004). Examining change in MetSyn components and anthropometric indices

across all individuals (with and without MetSyn) may present different relationships.

6.6.3.2 All individuals (with and without MetSyn)

Questions have been raised regarding whether the clinical treatment of metabolic abnormalities should be different in the presence or absence of MetSyn and currently, individual metabolic abnormalities of MetSyn are treated, not the MetSyn itself (Alhassan, 2008). When examining changes across individuals (those with and without MetSyn) in the present study, it is evident that there is a relationship between changes in MetSyn components and changes in anthropometric measures, thus justifying this treatment method. For example, decreases in BG, WC, SBP and DBP and an increase in HDL-C showed significant correlations with changes in at least 3 anthropometric measures. BMI, mass and WHR correlated with all of these MetSyn parameters, however mass was the only traditional anthropometric variable that changed significantly. Mesomorphy showed significant correlation with increases in HDL-C, decreased BG and reduced WC, however it did not show significant change over time. In contrast $\Sigma 8SF$ decreased significantly and showed significant correlations with decreases in WC and DBP. The changes in the MetSyn components were minimal with only BG significant reduction over time.

In defining eligibility criteria to participate in a particular study, or to make inferences regarding MetSyn and disease risk, all 4 clinical criteria for MetSyn are currently used in literature (Alhassan et al., 2008) and the question remains whether these clinical criteria identify similar or different individuals. However, whilst there is controversy surrounding the clinical criteria used to identify MetSyn, it is widely accepted that regardless of the criteria used weight reduction has been shown to significantly improve all MetSyn components (Alhassan et al., 2008). Among all individuals in the present study (those with and without MetSyn) body mass significantly reduced by 1.9 ± 0.7 kg. This showed significant correlation with change in all

MetSyn components with the exception of TG (Table 6.9). However, the reduction in BG ($1.4 \pm 0.2 \text{ mmol.L}^{-1}$), was the only significant reduction of all MetSyn components.

Researchers such as Corrigan et al. (1991) have identified that weight loss can reduce blood pressure in overweight hypertensive patients, and weight loss is considered an effective method for primary prevention of hypertension (Stevens et al., 2001). Furthermore, in a review of four randomised controlled trials (RCTs) examining overweight non-hypertensive patients ($n=872$) the same relationship between weight loss and reduced blood pressure was observed (Cutler, 1991). In a meta-analysis of 25 RCTs comprising 4874 participants, an estimated reduction of $-1.1/-0.9 \text{ mmHg}$ was observed per kg weight loss, by means of energy restriction, physical activity, or both (Neter et al., 2003). These values are substantially smaller than estimates from a previous meta-analysis of 12 trials by Staessen et al. (1988) who identified a $-2.4/-1.5 \text{ mmHg}$ reduction per kg. However, as noted by Neter et al., (2003), only 2 trials overlapped within the meta-analyses which might explain this discrepancy. Furthermore, half of the studies in the meta-analysis by Staessen et al. (1988) were not randomised.

There are several potential biological pathways that may be responsible for these findings although the exact mechanism of the relation between hypertension and obesity and effects of weight loss on blood pressure is unknown (Neter et al., 2003). A central feature of obesity-associated hypertension is related to abnormalities in sympathetic nervous system and the renin-angiotensin-aldosterone system that cause changes in sodium handling (Engeli & Sharma, 2001). Grassi et al., (1995) suggest that human obesity is associated with a marked sympathetic activation and that this activation, observed in obese normotensive participants, may be one of the factors facilitating the development of hypertension. Engeli & Sharma (2001) suggest that the renin-angiotensin-aldosterone system is overactivated in obese participants (Engeli & Sharma, 2001) and excessive aldosterone production observed in obese participants is thought to contribute to

maladaptive processes that contribute to the development of hypertension (Sowers, Whaley-Connell & Epstein, 2009).

Improvements in glycemic control are also seen with modest weight reduction of <10% (Goldstein, 1992). The significant correlations observed between reduction in BMI and mass with reduction in BG (Table 6.9) provide support for this. It is worth noting however that of these two anthropometric variables, mass was the only one to show significant change over time, showing a 2% reduction. Decrease in WHR also showed the same strength of correlation as BMI and mass with reduced BG ($r=0.42$). WHR has been found to be independently associated with impaired glucose tolerance (Sakurai et al., 1995). Moreover, this relationship has been identified within and across sexes (Bertrais, 1999) although is less consistent across ethnic groups (Patel et al., 1999).

In the present study, mesomorphy also showed a moderate significant correlation with blood glucose (Table 6.9). This is again in agreement with research that considers mesomorphy to be the most important somatotype component when explaining the variance in blood lipids and cholesterol levels (Katzmarzyk et al., 1998). However, of the somatotype components, endomorphy was the only one to show significant change over time, reducing from 6.3 ± 1.4 to 5.5 ± 1.8 . Parallel to examining change over time in individuals with MetSyn, when examining change in all individuals endomorphy and $\Sigma 8SF$ both showed significant decreases. Again, although these changes suggest positive changes in body composition, the lack of correlation between these variables and MetSyn components limits their usefulness in identifying individuals at risk.

6.6.4 Limitations

It is important to note that genetic susceptibility could play a major role in the expression of the MetSyn (Grundy, 2003) and thus could have influenced the results obtained. Furthermore, the separate treatment of somatotype

components could have confounded the results and may explain some of the non-significant interpretations.

This study did not obtain valid information about dietary intake or physical activity patterns, thus no inference of the possible influence that these factors may have on the MetSyn components can be made. This may also provide possible explanation for the modest changes observed, which preclude meaningful interpretation of correlations observed between changes in body composition and changes in MetSyn parameters. Furthermore, only 14 of the 26 participants that completed the study met the criteria for MetSyn. Thus a larger study, consisting of individuals with a diagnosis of MetSyn, may have sufficient power to demonstrate an association between change in anthropometric measures and change in MetSyn parameters.

6.6.5 Future directions

Whilst studies have attempted to control for behavioural variables such as physical activity and dietary habits, a study utilising a direct comparison is needed to assess the relative contribution these factors have on the MetSyn. It is well known that independent of weight loss exercise can have beneficial effects in reducing blood pressure and BG levels and increasing HDL-C levels. However the separate effects of exercise intensity, duration and frequency are less well known and warrant further investigation. Assessing changes in MetSyn parameters in response to pharmacological intervention also warrants attention, as the role of such therapy in the absence of lifestyle changes, is as yet, unclear.

It is also plausible that the MetSyn may manifest itself as a function of sample characteristics, such as gender and ethnicity. Further studies investigating these differences may identify the influence of these sample characteristics to inform more applicable treatment modalities. Additional analyses, utilising factorial analysis to examine the separate and combined

effects of somatotype, may also provide further insight into the relationship between somatotype and MetSyn parameters.

6.7. Conclusion

Traditional anthropometric measures, namely BMI and mass, showed stronger correlation with MetSyn markers at baseline than alternative anthropometric measures. Therefore H_8 , that alternative anthropometric measures would show stronger correlation with MetSyn markers compared to traditional anthropometric measures, is rejected. Furthermore, when examining the association between changes in traditional and alternative anthropometric measures with changes in MetSyn markers, the strongest relationships were evident in traditional anthropometric measures. Thus H_9 that changes in alternative anthropometric measures would show a stronger correlation with changes in MetSyn markers compared to changes in traditional anthropometric measures and changes in MetSyn markers, is also rejected.

Across all individuals strong linear relationships were found with weight loss and improvement of each of the MetSyn components, this is in agreement with results of other investigations conducted on the general population and highlights the importance of weight as an indicator of health status and change in health. However, in contrast to previous research, few correlations between alternative anthropometric measures and MetSyn components were evident in the present study, and those that were appeared to add little value in identifying at risk individuals or monitoring health status. Therefore, it is concluded that in light of the increased time and expertise required to acquire these variables, their applicability as a health measure is limited and body mass and BMI (traditional measures) may be more effective measures. Furthermore, the number and strength of relationships between change in traditional anthropometric variables and change in MetSyn components increased when examining all individuals as opposed to focusing on individuals with MetSyn alone. It therefore seems justified to take a

preventative approach and focus on individuals with any of these risk factors, particularly as it is well documented that not all individuals display a clustering of these risk factors.

7. CONCLUSIONS, PRACTICAL IMPLICATIONS AND FUTURE RESEARCH DIRECTIONS

This chapter revisits the original aims of the studies that comprise this thesis, and provides a summary of thesis findings and the practical implications of each study. Limitations of the body of work are considered and building on these limitations, future directions for both research and practice involving overweight and obese individuals will be identified.

7.1. Revisiting original aims

7.1.1 Study One

By definition, obesity is an excess of body fat. Therefore to accurately assess an overweight individual, a method must be available that is capable of measuring body compartments (Kushner et al., 1990) and the need for measures that are sensitive to change has been recognised (Deitel et al., 2007; Teixeira et al., 2005). Furthermore, for clinical reasons these methods should be simple and reliable (Sharma & Kushner, 2009). The limitations of weight-related parameters for providing reliable assessment of body fat and its distribution over time are well documented (Burkhauser & Cawley, 2008; Garcia et al., 2005; Nevill et al., 2006; Sharma & Kushner, 2009). Other advanced techniques that achieve reliable results require expensive instrumentation, are impractical for individual use and cannot be easily transported to test sites in large-scale intervention and epidemiology projects (Foreyt & Jeor, 1997; Van Loan, 1997). Somatotyping, a technique used to summarise the physique as a unified whole requires relatively inexpensive tools that are portable (Bellisari & Roche, 2005), and when used correctly can provide valid results (Stewart, 2003) and can be laboratory based or field based (Norton & Olds, 1996). Commonly used to describe the changes in physique during growth, ageing and training (Duquet & Carter, 2001), this technique may also identify changes in composition of obese individuals.

Study One therefore aimed to compare the change of traditional anthropometric measures with alternative anthropometric measures in order to identify the most discernible measure of change.

7.1.2 Study Two

The detrimental psychological consequences of obesity have been recognised (Rippe et al., 2004; Schwartz & Brownell, 2004; Wadden et al., 2006) and how humans perceive themselves is thought to have particular importance on psychological health (Carron et al., 2003). Physical self-perceptions have been examined in relation to obesity, both in terms of composition changes and cross-sectional comparisons (Polman & Brokoles, 2007; Shaw et al., 2000). However, research to date has been equivocal and little research has examined the association between somatotype and physical self-perceptions. Identifying objective anthropometric measures that relate to physical self-perceptions, and understanding their interaction, may inform appropriate feedback mechanisms for improved management of overweight and obese individuals. Study Two therefore aimed to investigate the relationships between traditional and alternative anthropometric measures with physical self-perception and examine the association between changes in anthropometric measures and changes in physical self-perceptions.

7.1.3 Study Three

The increasing prevalence of obesity has been accompanied by a parallel increase in the prevalence of the MetSyn (Liberopoulos et al., 2005). Weight reduction is a priority for the management of MetSyn and the effects of weight loss on MetSyn risk factors have been extensively studied (Hall et al., 2006). Although under-researched, there is some limited documented evidence of characteristic somatotypes being associated with some diseases and conditions (Herrera et al., 2004) and it is recognised that the use of somatotyping, a more holistic measure of one's body, may have utility in

evaluating an individual's metabolic risk (Katzmarzyk et al., 2003). Identifying anthropometric measures that correlate with MetSyn markers may be helpful in both identifying individuals at risk and improving management of MetSyn. Therefore Study Three aimed to investigate the relationships between traditional and alternative anthropometric measures with MetSyn markers and examine the association between changes in anthropometric measures and changes in physical self-perceptions.

7.2 Summary of findings and practical implications

The work described in this thesis has been concerned with the identification of anthropometric measures that are sensitive to changes in body composition of overweight and obese individuals, and examining their association with physiological and psychological health markers.

Main findings of Study One highlight that the alternative anthropometric measures $\Sigma 8SF$ and endomorphy and the traditional anthropometric measure %BF, were able to identify significant change that other traditional anthropometric parameters were unable to detect (Table 4.12). $\Sigma 8SF$ and endomorphy showed comparable magnitudes of change to both BMI and %BF over the year (Fig. 4.15). However BMI does not account for changes in body composition and %BF suffers from population specific limitations and the need for sophisticated techniques to obtain reliable results that are impractical in most population studies. The best use of SF measurements is as raw values, where they act as reliable indices of regional fatness, as opposed to being transformed to other measures such as %BF. The current study has demonstrated that $\Sigma 8SF$ is sensitive to change (Fig. 6.5). As this alternative anthropometric measure represents change in the composition of the body, focusing on this may be a potential means for reducing attrition rates commonly seen in weight loss interventions and improving participant motivation. Additionally, the use of such measures that reduce the central focus of weight change to define success, may also aid the transition of individual's to a healthier lifestyle and reduce the dramatic disparity between

recommended weight loss goals and individual's actual weight loss goals. Therefore it is concluded that $\Sigma 8SF$ could be used to monitor weight loss in overweight/obese individuals. The somatotype sub-component endomorphy was the only sub-component to show significant change at interim periods and to show greater magnitudes of change than a traditional anthropometric measure (mass and WHR). The strength of somatotyping is its three-number rating, representing the physique as a unified whole. Furthermore, collection of somatotype data requires considerable skill and expertise. Therefore, it is concluded that somatotyping is not considered for routine use for monitoring weight loss in overweight/obese individuals.

The findings of Studies Two and Three highlight that overweight and obese individuals are presented with the challenge of coping with physical, physiological and psychological changes during weight loss attempts. Therefore, researchers are encouraged to assess both physiological and psychological functioning, when examining overweight and obese individuals. Additionally, from a public health perspective, strategies and interventions developed to treat obesity should consider a more holistic approach to treatment, aiming to improve both physiological and psychological functioning.

Correlational analyses in Study Two suggest the relationship between traditional and alternative anthropometric measures and the physical self is significant in overweight/obese individuals. These data provide a rationale for future research to further examine the extent of this relationship. Results highlighted that initially individual's changes in physical self-perceptions were a result of cognitive changes; however, perceptions become more objective over time, relating to physical changes. Physical self-perceptions have been found to be moderate predictors of physical activity and physical activity has been identified as the single most important behavioural factor in long-term weight management in obese people. Thus this gives rise for the consideration of an educational component within all weight management programmes that focus on enhancing physical self-perceptions, as opposed

to solely focusing and defining success on measures of weight change. There was no difference in the strength of relationships between traditional and alternative anthropometric measures with PSPP constructs. It is therefore concluded that, due to the time and expertise required to calculate somatotype and $\sum 8SF$, the use of these measures in physical self-perception research cannot be supported at this time.

Main findings of Study Three identified moderate relationships between weight loss and improvement in MetSyn components, highlighting the utility of weight as a health indicator and a measure of change in health. Few correlated variables showed significant change over time and the number of correlations increased when examining all individuals compared to those with MetSyn alone. This suggests that from a clinical perspective anthropometric measures may be better applied in identifying at risk individuals. Furthermore this provides justification to take a preventative approach to MetSyn, focusing on individuals with any of these risk factors, particularly as it is well documented that not all individuals display a clustering of MetSyn risk factors. Overall, changes in alternative anthropometric measures showed weaker correlation with changes in MetSyn components compared to traditional anthropometric measures. Thus it is concluded that the clinical utility of these alternative anthropometric measures to assess change in MetSyn status appears limited.

In conclusion, $\sum 8SF$ and endomorphy showed comparable magnitudes of change to BMI and %BF and showed significant change over time. However, as $\sum 8SF$ represents changes in body composition and is a sensitive measure that can be used in its raw form, this measure could be of greater benefit than BMI and %BF to monitor change in the body composition of overweight and obese individuals. Conversely, the benefits of somatotyping over traditional anthropometric measures are less evident and should not be solely used for this purpose.

It is noted that the measurement of skinfolds should only be utilised provided there is adherence to established protocols and the use of experienced personnel. Furthermore, this measure is acceptable for use in large population-based studies due to the portable and inexpensive equipment required. However when assessing individuals for critical health reasons relating to MetSyn, alternative anthropometric measures appear to have limited clinical utility in identifying and monitoring at risk individuals. From a psychological perspective, the application of alternative measures in physical-self perception research requires further examination before firm conclusions can be made regarding their practical implications. However, it is identified that there is a relationship between both traditional and alternative anthropometric measures and physical self-perceptions. Thus focusing on other aspects related to maintaining a healthy weight, such as an active lifestyle and improved dietary habits, as opposed to anthropometric measures that are associated with negative physical self-perceptions, may be a more constructive approach to address obesity and psychological well-being.

To conclude, somatotyping appears to have limited utility for monitoring change in overweight/obese individuals and no obvious benefit in assessing an individual's health status from a physiological or psychological standpoint. However, $\Sigma 8SF$, that reflects changes in body composition and is sensitive to change, may be a useful measure to monitor weight loss in overweight/obese individuals.

7.3 Limitations

Although this study has made positive contributions to the literature in that the discernibility of a range of anthropometric measures to measure change in an overweight/obese people has been established, and the relationship between these anthropometric measures with metabolic syndrome markers and physical self-perceptions measures identified, it is important to acknowledge the studies limitations. Specific limitations pertaining to each

study are provided in previous chapters; however the main limitations are discussed here.

Due to attrition, a common occurrence in obesity research, the sample size was relatively small. Despite this, adequate power for significant differences and correlational relationships was observed. However, a larger sample size would provide means for increased confidence in research findings. Furthermore, no attempt was made to control for lifestyle variables that may influence body composition and physiological and psychological health, and there was a lack of valid information regarding physical activity levels and nutritional intake of the participants in the studies. This precludes any insight into the mechanisms that contribute to weight and body composition changes.

Whilst standardised procedures were followed for the collection of anthropometric data, and satisfactory TEM and coefficient of reliability ranges demonstrated the anthropometrist's skill and precision, overall weight loss and body composition changes in the present study were modest. Therefore, as change was not calculated using confidence intervals, it is noted that measurement error may have confounded results. Furthermore, it is important to acknowledge that a number of different measurement protocols are utilised in research studies that purport to measure the same thing. Therefore, although the standardised procedures of ISAK were adhered to throughout the duration of the studies that comprise this thesis, when comparing the study's results to other published literature, it is important to acknowledge that different measurement protocols may have been followed.

7.5 Future directions

There are a number of future research directions that emerged from the current investigations. Whilst the aim of interventions should be to reduce obesity and related health issues, potential mediators and moderators need

to be investigated. Studies are strengthened by homogeneous samples in order to investigate specific relationships, a larger heterogeneous population that can be stratified according to gender, or obesity status (e.g. overweight, obese, morbidly obese). Considering the effects of gender and age on changes in body composition and associated health issues may aid the development of population specific interventions. Thus future research should aim to include an equal male to female ratio, to control for any gender effects that may arise, and consider participants degree of obesity, in order to generalise results to larger populations.

Future studies should also attempt to collect valid information regarding participants' physical activity and dietary habits and moreover, assess body composition changes in participants following different treatment modalities, in order to assess the efficacy of weight loss methods. Additional research should also examine the utility of individual skinfold measures, or a smaller subset of skinfold measures, in identifying change. Lastly, future research should endeavour to establish an optimal monitoring frequency to determine the most practical and useful research design, in order to reduce the economic implications of obesity research from both a time and financial perspective, whilst maintaining an appropriate level of support to the obese individual.

7.6 Final comment

The reality is that the most accurate procedures for estimating body fat are also the most complicated, expensive, and clinically impractical. Although current anthropometric measures, such as body mass and BMI, serve their function and should continue to be reported so that the costs and benefits of alternative measures can be clarified, these measures should be complimented by alternative measures. There may not be a single measure that is best for every application; however greater consideration of alternative measures of obesity (namely $\sum 8SF$) in monitoring changes in body composition and associated health issues may enrich research on obesity.

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Appendix 1 – Anthropometry accreditation levels

The four levels of technical expertise including; technician (restricted profile), technician (full profile), instructor and criterion anthropometrist are:

- Level 1 (technician); restricted profile; a person who can demonstrate adequate technical precision in measuring stretch stature, mass, the 9 skinfolds, 5 girths, and 2 breadths of the 'restricted' anthropometric dimensions.
- Level 2 (technical – full profile); a person who can demonstrate adequate technical precision in all of the 40 anthropometric dimensions
- Level 3 (instructor); in addition to technical competence, a level 3 person has adequate theoretical knowledge about anthropometry to be able to instruct and accredit level 1 and 2 anthropometrists.
- Level IV (criterion anthropometrist); a criterion anthropometrist has many years of experience in taking measurements, has a high level of theoretical knowledge, has been involved in several large anthropometric projects and has a publication record in anthropometry.

(Norton & Olds, 1996)

Appendix 2 – Restricted and full anthropometric profiles

Anthropometric measurements included in a Level 1 restricted profile:

Skinfolds	Girths	Bone Breadths
Triceps	Arm (relaxed)	Humerus
Subscapular	Arm (flexed & tensed)	Femur
Biceps	Waist (minimum)	
Iliac crest	Gluteal (hips)	
Supraspinale	Medial calf (maximum)	
Abdominal		
Front thigh		
Medial calf		
Mid-axilla		

Anthropometric measurements included in a Level 2 restricted profile:

Skinfolds	Girths	Lengths	Breadths/Lengths
Triceps	Head	Acromiale-radiale	Biacromial
Subscapular	Neck	Radiale –stylium	Biiliocrystal
Biceps	Arm (relaxed)	Midstylium – dactylium	Foot length
Iliac crest	Arm (flexed & tensed)	Iliospinale-box height	Sitting height
Supraspinale	Forearm (maximum)	Trochanterion-box height	Transverse chest
Abdominal	Wrist (distal stylioids)	Trochanterion-tibiale laterale	AP chest
Front thigh	Chest (mesosternale)	Tibiale-laterale	Humerus
Medial calf	Waist (minimum)	Tibiale-mediale-sphyrion tibiale	Femur
Mid-axilla	Gluteal (hips)		
	Thigh (1cm below gluteal)		
	Thigh (mid-trochanterion tibiale laterale)		
	Medial calf (maximum)		
	Ankle (minimum)		

(Norton & Olds, 1996)

Appendix 3 – Anthropometry equipment

Anthropometric equipment needed to complete a Level I restricted anthropometric profile:

Anthropometry Tape: a flexible steel tape (calibrated in centimetres with millimetre gradations) is recommended for girth measurements. The Lufkin (W606PM) is the preferred metal tape.

Stadiometer: is required for measuring stature. A sliding head piece that lowers to the vertex of the head is recommended.

Weighing Scales: are required for the measurement of body mass. The use of electronic scales is increasing and the accuracy of some of these scales are equal to or greater than that of the traditionally used beam balance, provided calibration of both machines is maintained.

Skinfold Calipers: are used for the measurement of skinfolds. Harpenden calipers have been used as the criterion instrument by ISAK reporting a compression of $10\text{g}\cdot\text{m}^{-2}$ in new calipers.

Segmometer: can be used to aid landmarking. Manufactured from a steel carpenter's tape which has attached two straight branches, each approximately 7cms in length.

Small sliding calipers: these calipers are used for biepicondylar humerus and femur breadths.

Anthropometry Box: can be used to aid the taking of measurements by asking the subject to stand or sit on the box. This box should have dimensions with all side lengths of approximately 40cms.

(Norton & Olds, 1996)

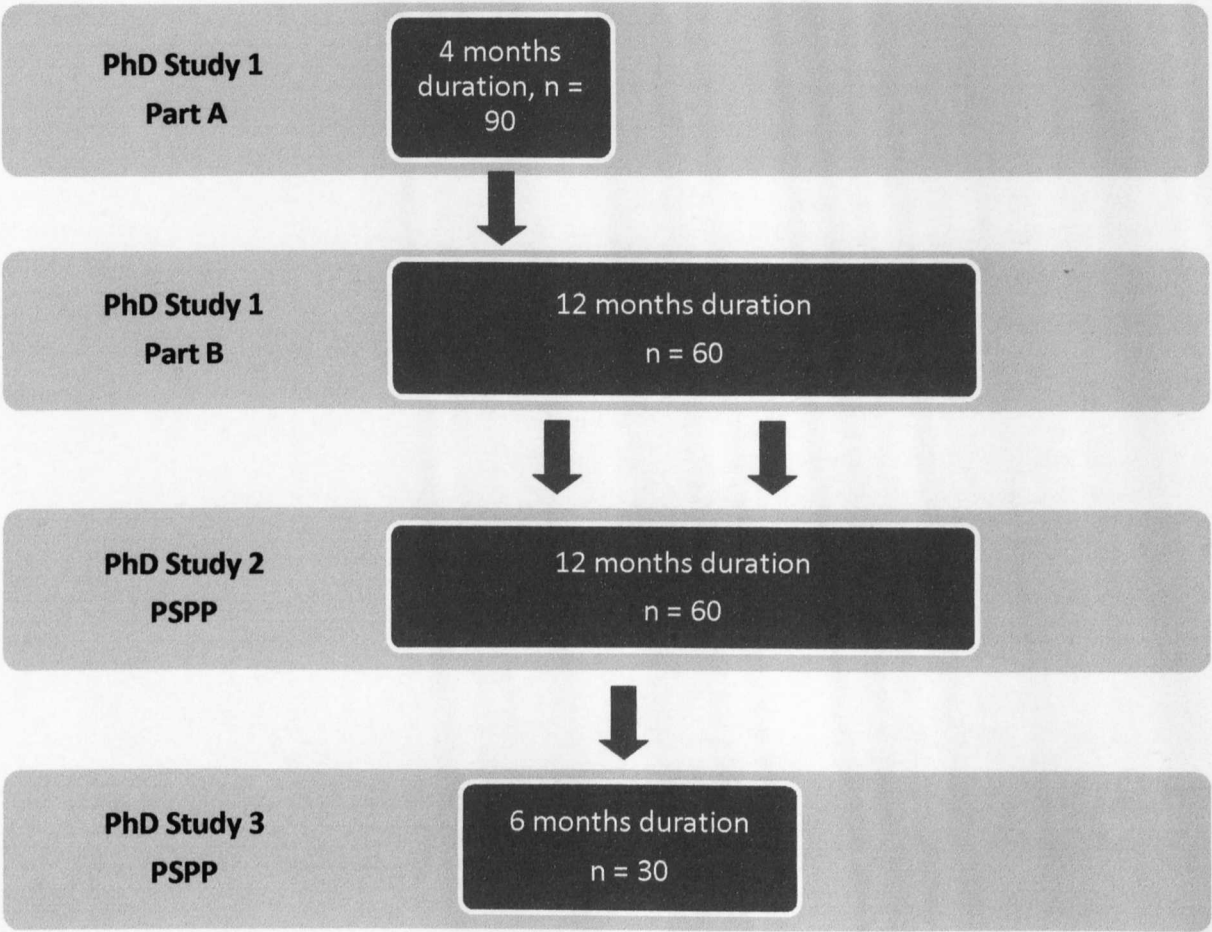
Appendix 4 – Intra- and inter-technical error of measurement accreditation levels

Anthropometrists' intra- and inter-technical error or measurement for all accreditation levels (a) following the training course and (b) following performance of 20 repeated profiles:

		Level 1		Level 2		Level 3	
		a	B	A	B	a	B
		Post-course	Post-profiling	Post-course	Post-profiling	Post-course	Post-profiling
Inter-tester	Skinfolds	12.5%	10.0%	10.0%	7.5%	10.0%	7.5%
	Other	2.5%	2.0%	2.0%	1.5%	2.0%	1.5%
Intra-tester	Skinfolds	10.0%	7.5%	7.5%	5.0%	7.5%	5.0%
	Other	2.0%	1.5%	1.5%	1.0%	1.5%	1.0%

(Norton & Olds, 1996)

Appendix 5 – Flowchart of participants progression through Studies One, Two and Three



Appendix 6 - Participant information sheet (Study One and Study Three)

You are asked to read this form carefully. If you consent to take part then you should sign the consent form. If you have any query, or are unsure or uncertain about anything, then you should not sign until you problem has been resolved and you are completely happy to partake.

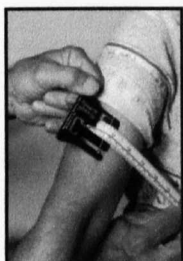
The programme for which you are being asked to volunteer is being carried out in order to monitor the body composition changes that occur during weight loss. Body composition is a technical term used to describe the different components that make up a person's body weight, and refers primarily to the distribution of muscle and fat in the body. Various health measures and body composition will be measured each month on a one-to-one basis.

A



Your blood pressure will be recorded using a standard blood pressure monitor and will involve you wearing an arm cuff for a short while (A).

B



In order to determine your body composition, various measurements of your body will be taken, such as circumferences and simple skinfold-thickness measurements. These will be measured using a measuring tape (B) and a device called a skinfold caliper (C).

C



These measurements are painless and will be carried out in a private environment with no-one present other than the measurer. You are asked to wear loose fitting clothing when you are having your measurements recorded and it is estimated that the recording of these measurements will require approximately 45 minutes to one hour.

Body Mass Index (BMI) is a tool used for indicating weight status in adults. It is a measure of weight for height. This project is primarily aimed at individuals with a BMI between 27 and 35. If your BMI falls below 27 we can offer alternative arrangements to provide you with support in your effort to reduce your BMI into the normal weight range. If your BMI is above 35 it is likely that you will require more rigorous intervention from external sources,

such as dietetic support. We will be pleased to offer you advice in this process.

At each monthly meeting you will be asked to complete a questionnaire. This questionnaire is designed to assess perceptions of the physical self in the domains of *physical condition*, *body attractiveness*, and *physical self worth*.

Additionally, in between appointments you will be asked, at random, to complete a 3 day diet and exercise log. The aim of this is to monitor and identify lifestyle habits so improvements can be suggested.

You may at any time withdraw from the experiment. You do not have to give any reason, and no one can attempt to dissuade you. If you ever require any further explanation, please do not hesitate to contact the people listed below.

Any information obtained during this trial will remain confidential as to your identity: if it can be specifically identified with you, your permission will be sought in writing before it will be published. Other material, which cannot be identified with you, will be published or presented at meetings with the aim of benefiting others. All information will be subject to the conditions of the Data Protection Act 1998 and subsequent statutory instruments.

This trial has received ethical and scientific approval to be undertaken, in accordance with current University regulations.

Contact Details:

Principal Measurer

Nikki Brown

Tel: 02392 XX XXXX

nikki.brown@xxxxxxxxx

Appendix 7 - Physical activity readiness-questionnaire (PAR-Q)

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise and the completion of the PAR-Q is a sensible step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problems or hazards. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate for those who should seek medical advice concerning the type of activity most suitable for them.

Common sense is your best guide to answering these few questions, please read them carefully and circle YES or NO, as appropriate.

1. Has your doctor ever said that you have heart trouble? **YES/NO**
 2. Do you frequently have pains in your heart and chest? **YES/NO**
 3. Do you often feel faint or have spells of severe dizziness? **YES/NO**
 4. Has a doctor ever said your blood pressure was too high? **YES/NO**
 5. Has your doctor ever told you that you have bone or joint problems such as arthritis that has been aggravated by exercise or might be made worse by exercise? **YES/NO**
 6. Is there any good physical reason not mentioned here why you should not follow an activity programme even if you wanted to? **YES/NO**
 7. Are you aged 65+ and not accustomed to vigorous exercise? **YES/NO**

YES to one of more questions:

If you have not recently done so, consult with your GP by telephone or in person BEFORE increasing your physical activity and/or taking a physical assessment. Tell your GP which questions you answered YES to on the PAR-Q or present your PAR-Q copy to him/her.

NO to all questions:

If you answered the PAR-Q accurately, you have reasonable assurance of your present suitability for a:

- a) Graded exercise programme, gradually increasing in intensity to aid fitness development with minimal discomfort

b) Fitness assessment by a qualified trainer.



Programmes:

After medical evaluation, seek advice from your GP regarding your suitability for:

- Unrestricted physical activity starting off easily and progressing gradually.
- Restricted or supervised activity to meet your specific needs at least on an initial basis

Postpone:

If you have a temporary minor illness such as a common cold.

Appendix 8 - Consent form (Study One and Study Three)

I have read the information sheet, which provides full details of this study, and have had the opportunity to raise and discuss my questions with either the Project Officer: Dr Clare Hencken or the Principal measurer: Nikki Brown. I understand what is expected of me with regard to the general nature, object, potential risks and duration of the study.

I understand that the aim of the programme is to monitor the body composition changes that occur during weight loss. Body composition is a technical term used to describe the different components that make up a person's body weight, and refers primarily to the distribution of muscle and fat in the body. Various health measures and body composition will be measured each month on a one-to-one basis.

I agree to volunteer as a participant for the study described in the information sheet, I give my full consent to my participation in this study. This consent is specific to the particular study described in the information sheet attached, and shall not be taken to imply my consent to participate in any subsequent data collection or deviation from that detailed here.

I reserve the right to withdraw from this study at any time; I also understand that I may be withdrawn at any time, and will suffer no penalty as a result.

Name.....
Project Officer/Principal measurer

Signed.....
Name..... Date.....

Witnessed.....
Name..... Date.....

Appendix 9 - GP referral form

To whom it may concern,

Re: _____

D.O.B: _____

The above named patient has volunteered to be a participant in a research project at the University of Portsmouth. This project is a monitoring and support programme to assist those who wish to lose weight. It involves monthly meetings incorporating anthropometrical assessment to appraise the quality of body composition and monitors additional indices of health such as resting HR and blood pressure. The project is funded via the University of Portsmouth and its duration spans 12 months for each participant to aid adherence and retention.

Although the programme itself does not advocate one specific physical activity or diet programme, guidance and advice will be provided to encourage participants to engage in some form of diet plan and exercise programme. In preparation for this programme, we have asked your patient to complete a PAR-Q questionnaire to establish any existing medical problems. We have also undertaken tests of resting HR, resting SBP and resting DBP.

We are referring them to you because a potential risk (please see attached form/s) has been identified that requires a GP's evaluation to establish suitability for:

- an unrestricted physical activity programme starting off easily and progressing gradually **or**
- a restricted or supervised activity incorporating a fitness assessment by a qualified trainer.

We would very much appreciate it, if you consider increased physical activity suitable for your patient, if you would sign the enclosed form for the patient to return to us.

If you have any further questions, please do not hesitate to contact

Project leader

Dr Clare Hencken

Tel: 02392 XX XXXX

E-mail: clare.hencken@xxxxxxxxx

Principal measurer:

Nikki Brown

Tel: 02392 XX XXXX

E-mail: nikki.brown@xxxxxxxxx

Appendix 10 – Participants food and exercise diary

FOOD AND EXERCISE DIARY

- Sometimes we are unaware of the amount of food we actually eat in one day.
- Keeping a diary can help you become more aware of eating and activity habits, and identify problem areas.
- It may also help in other ways such as:
 - Giving you a basis from which to plan changes.
 - Keeping you focused on your goals and monitor changes.
 - Encouraging you to make conscious choices about what you eat & do.

WHAT TO DO

- Write down everything you eat and drink over the day, for three days.
- It's hard to remember what you've eaten at the end of the day, so try to record things as you go.
- Be sure to write down the time of the day and the amount you eat.
- It can also help to make a note of any thoughts or feelings linked to eating, especially if you find you often eat for comfort or when you're not actually hungry.

Here is an example:

Time	Food/Drink Item	How Much	Where/Who With	Mood/Thoughts
8am	Orange juice.	1 glass	Home with family	Rushing to get everything organised
9am	Choc-chip cookies. Coffee.	2 1 large mug	Coffee shop - alone	Stressed, needed something sweet
Noon	Cheese & ham sandwich Packet of crisps Diet coke	2 rounds - white bread Ready salted (walkers) 1 large glass	Alone, watching TV	Bored

It also helps to track your activity.

- Include chores and housework as activity as well as any kind of structured activity or exercise.
- Remember to record how long you take part in the activity and how hard you worked.
- Try using a scale of 1-10 to indicate how hard you are working. 1 = really easy, 10 = working really hard.
- It's also worth jotting down how you were feeling before/during/after your activity. It might remind you how good you felt last time and encourage you to do it again!

Time	Activity	Time Spent Doing Activity	How Hard Were You Working	Mood/Thoughts
12:30pm	Walking	30 minutes	6	Felt tired but once I got started felt more energetic
6pm	Hoovering	20 minutes	5	Usually takes 30 mins but worked harder
7:30pm	Aerobics Class	50 minutes	8	Went with a friend, good motivation 236

Food Diary

DAY 1:

Time	Food/Drink Item	How Much	Where/Who With	Mood/Thoughts

DAY 2:

Time	Food/Drink Item	How Much	Where/Who With	Mood/Thoughts

DAY 3:

Time	Food/Drink Item	How Much	Where/Who With	Mood/Thoughts

Exercise Diary

DAY 1:

Time	Activity	Time Spent Doing Activity	How Hard Were You Working	Mood/Thoughts

DAY 2:

Time	Activity	Time Spent Doing Activity	How Hard Were You Working	Mood/Thoughts

DAY 3:

Time	Activity	Time Spent Doing Activity	How Hard Were You Working	Mood/Thoughts

Appendix 11 - Physical Self-Perception Profile

WHAT AM I LIKE?

These are statements which allow people to describe themselves.

There are no right or wrong answers since people differ a lot.

First, decide which one of the two statements best describes you.

Then, go to that side of the statement and check if it is just
'sort of true' or 'really true' FOR YOU.

Really true for me	Sort of true for me				Sort of true for me	Really true for me
<input type="checkbox"/>	<input type="checkbox"/>	I am very competitive	BUT	I am not quite so competitive	<input type="checkbox"/>	<input type="checkbox"/>

REMEMBER to check only **ONE** of the four boxes

1.	<input type="checkbox"/>	<input type="checkbox"/>	I am not very confident about my level of physical conditioning and fitness	BUT	I always feel confident that I maintain excellent conditioning and fitness	<input type="checkbox"/>	<input type="checkbox"/>
2.	<input type="checkbox"/>	<input type="checkbox"/>	I feel that compared to most, I have an attractive body	BUT	I feel that compared to most, my body is not quite so attractive	<input type="checkbox"/>	<input type="checkbox"/>
3.	<input type="checkbox"/>	<input type="checkbox"/>	I feel extremely proud of who I am and what I can do physically	BUT	I am sometimes not quite so proud of who I am physically	<input type="checkbox"/>	<input type="checkbox"/>
4.	<input type="checkbox"/>	<input type="checkbox"/>	I make certain that I take part in some form of regular vigorous physical exercise	BUT	I don't often manage to keep up regular vigorous physical exercise	<input type="checkbox"/>	<input type="checkbox"/>
5.	<input type="checkbox"/>	<input type="checkbox"/>	I feel that I have difficulty maintaining an attractive body	BUT	I feel that I am easily able to keep my body looking attractive	<input type="checkbox"/>	<input type="checkbox"/>
6.	<input type="checkbox"/>	<input type="checkbox"/>	I am some-times not so happy with the way I am or what I can physically do	BUT	I always feel happy about the kind of person I am physically	<input type="checkbox"/>	<input type="checkbox"/>
7.	<input type="checkbox"/>	<input type="checkbox"/>	I do not usually have high levels of stamina and fitness	BUT	I always maintain a high level of stamina and fitness	<input type="checkbox"/>	<input type="checkbox"/>

8.	<input type="text"/> <input type="text"/>	I feel embarrassed by my body when it comes to wearing few clothes	BUT	I do not feel embarrassed by my body when it comes to wearing few clothes	<input type="text"/> <input type="text"/>
9.	<input type="text"/> <input type="text"/>	When it comes to the physical side of myself I do not feel very confident	BUT	I seem to have a real sense of confidence in the physical side of myself	<input type="text"/> <input type="text"/>
10.	<input type="text"/> <input type="text"/>	I tend to feel a little uneasy in fitness and exercise settings	BUT	I feel confident and at ease at all times in fitness and exercise settings	<input type="text"/> <input type="text"/>
11.	<input type="text"/> <input type="text"/>	I feel that I am often admired because my physique or figure is considered attractive	BUT	I rarely feel that I receive admiration for the way my body looks	<input type="text"/> <input type="text"/>
12.	<input type="text"/> <input type="text"/>	I always have a really positive feeling about the physical side of myself	BUT	I sometimes do not feel positive about the physical side of myself	<input type="text"/> <input type="text"/>
13.	<input type="text"/> <input type="text"/>	I feel extremely confident about my ability to maintain regular exercise and physical condition	BUT	I don't feel quite as confident about my ability to maintain regular exercise and physical condition	<input type="text"/> <input type="text"/>
14.	<input type="text"/> <input type="text"/>	I feel that compared to most, my body does not look in the best of shape	BUT	I feel that compared to most my body always look in excellent physical shape	<input type="text"/> <input type="text"/>
15.	<input type="text"/> <input type="text"/>	I wish that I could have more respect for my physical self	BUT	I always have great respect for my physical self	<input type="text"/> <input type="text"/>
16.	<input type="text"/> <input type="text"/>	I feel that compared to most I always maintain a high level of physical conditioning	BUT	I feel that compared to most my level of physical conditioning is not usually so high	<input type="text"/> <input type="text"/>
17.	<input type="text"/> <input type="text"/>	I am extremely confident about the appearance of my body	BUT	I am a little self-conscious about the appearance of my body	<input type="text"/> <input type="text"/>
18.	<input type="text"/> <input type="text"/>	I am extremely satisfied with the kind of person I am physically	BUT	I sometimes feel a little dissatisfied with my physical self	<input type="text"/> <input type="text"/>

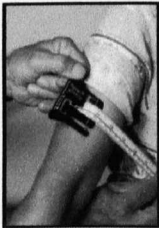
Appendix 12 – Physical self perception profile scoring sheet


PSPP Item Scores (r = reverse scoring)		
Physical Condition	Body Attractiveness	Physical Self-Worth
1:	2r:	3r:
4r:	5:	6:
7:	8:	9:
10:	11r:	12r:
13r:	14:	15:
16r:	17r:	18r:
Total:	Total:	Total:

Appendix 13 – Participation information sheet (Study Three)

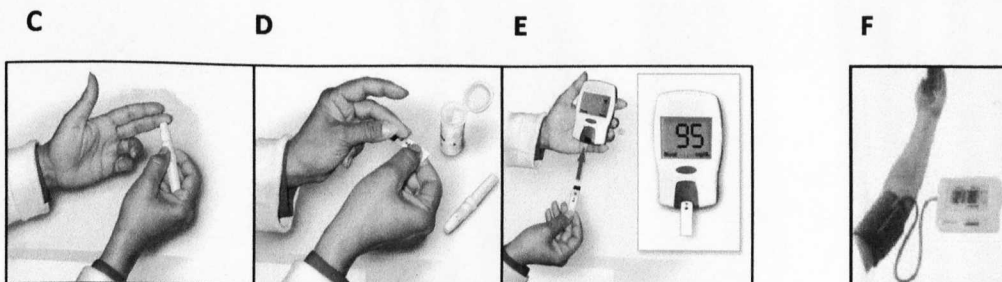
You are asked to read this form carefully. If you consent to take part then you should sign the consent form. If you have any query, or are unsure or uncertain about anything, then you should not sign until you problem has been resolved and you are completely happy to partake.

Amongst other things, this programme monitors body composition. Body composition is a technical term used to describe the different components that make up a person's body weight, and refers primarily to the distribution of muscle and fat in the body. In order to determine your body composition, various measurements of your body will be taken, such as circumferences and simple skinfold-thickness measurements. These will be measured using a measuring tape (A) and a device called a skinfold caliper (B).

A  These measurements are painless and will be carried out in a private environment with no-one present other than the measurer. You are asked to wear loose fitting clothing when you are having your measurements recorded and it is estimated that the recording of these measurements will require approximately 45 minutes to one hour.

B  The screening will enable us to provide you with information about your current health status. We will provide information about your body shape (somatotype) and frame as well as indications regarding your fat distribution. These measures will help us provide you with some guidance and suggestions for optimizing your health.

Cholesterol, blood glucose and triglyceride levels will be measured by a single finger prick to obtain a small blood sample (C). A small droplet of blood is then transferred to a test strip (D) and this test strip is then inserted in to the meter (E) to obtain your cholesterol/glucose measurement. Blood pressure will be recorded using a standard blood pressure monitor and will involve you wearing an arm cuff for a short while (F).



You will be required to fast for 12 hours prior to the measurements being taken, therefore we ask that you attend an early morning session in the Department of Sport & Exercise Science at the University of Portsmouth, having not consumed any food.

Any information obtained during this trial will remain confidential as to your identity: if it can be specifically identified with you, your permission will be sought in writing before it will be published. Other material, which cannot be identified with you, will be published or presented at meetings with the aim of benefiting others. All information will be subject to the conditions of the Data Protection Act 1998 and subsequent statutory instruments.

You may at any time withdraw from the programme. You do not have to give any reason, and no one can attempt to dissuade you. If you ever require any further explanation, please do not hesitate to contact the people listed below.

This trial has received ethical and scientific approval to be undertaken, in accordance with current University regulations.

Contact details:

Principal Measurer

Nikki Brown

Tel: 02392 XX XXXX

nikki.brown@xxxxxxxxx

Appendix 14 - Consent form (Study Three)

Please **initial the boxes** and sign below:

1) I have read the information sheet, which provides full details of the blood screening, and have had the opportunity to raise and discuss my questions with either the Project Officer: Dr Clare Hencken or the Principal measurer: Nikki Brown. I understand what is expected of me with regard to the general nature, object, potential risks and duration of the programme.

☐

2) I understand that in addition to the body composition measures and health measures that will be taken, measures of cholesterol, blood glucose and triglyceride levels will also be taken.

☐

3) I give my full consent to my participation in this programme. This consent is specific to the particular details described in the information sheet attached, and shall not be taken to imply my consent to participate in any subsequent data collection or deviation from that detailed here.

☐

4) I understand that my participation is voluntary and that I am free to withdraw at any time and will suffer no penalty as a result.

☐

Signed.....

Name.....

Date.....

Witnessed.....

Name.....

Date.....

Name.....

Project Officer/Principal measurer